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TOS EVALUATION CENTER (TEC) POSTOPERATIONAL TEST RESULTS FOR ESSA 4

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TOS EVALUATION CENTER (TEC) POSTOPERATIONAL TEST RESULTS FOR ESSA 4

Robert R. Golden
Goddard Space Flight Center
and
Duane A. Kaeding and David E. Briggs
RCA Service Company

January 1969

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

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TOS EVALUATION CENTER (TEC) POSTOPERATIONAL TEST RESULTS FOR ESSA 4

INTRODUCTION

In late 1967, ESSA* 4 came to the end of its usefulness as an operational spacecraft. Camera 1 had failed; camera 2 no longer produced usable pictures; and one data bit of the digital solar-aspect indicator (DSAI) was inoperative.

However, ESSA 4 even in this condition represented an opportunity to examine and evaluate a functional, nearly complete spacecraft with no loss of operational data. It could provide information that had never been obtained from operational spacecraft: programming pictures in the dark, for instance, or at high gamma and roll angles. The TOS Evaluation Center (TEC) therefore set up a program of four groups of progressively hazardous tests. This report describes the tests and their results.

Objectives of the four groups of tests were:

- To determine the aging or degradation of spacecraft subsystems as compared with their performance at launch checkout
- To exercise commands and subsystems not previously used
- To ascertain the thermal and power limitations of TOS spacecraft
- To use ESSA 4 as a test vehicle in special investigations of the command system, QOMAC** system, etc.

The test plan consolidated the items to be tested (Table 1) into four groups containing tests of a similar nature, carried out in order of increasing hazard to the spacecraft.

Group 1

1. Measure degradation of spacecraft receiver.
2. Measure video levels of both cameras in spacecraft darkness and spacecraft sunlight/earth darkness.
3. Test vulnerability of the command system.

*Environmental Science Services Administration
**Quarter-orbit magnetic attitude control

Table 1
Status of ESSA 4 Subsystems
At Turnoff, May 5, 1968†

Subsystem	Condition	Date
Programmer 1	Good	4/26/68 *
Programmer 2	Good	5/2/68 *
Beacon transmitter 1	Good	11/15/67*
Beacon transmitter 2	Good	5/5/68 *
HCI**-1 A	Good	5/27/67 *
HCI-1 B	Good	5/5/68 *
HCI-2 A	Good	5/27/67 *
HCI-2 B	Good	5/5/68 *
Regulator 1	Good	4/24/68 *
Regulator 2	Good	5/5/68 *
TV transmitter 1	Good	1/16/68 *
TV transmitter 2	Good	5/5/68 *
MASC*** coils	Good	5/5/68 *
MBC**** coils	Good	4/12/68 *
Camera 1	Failed	1/28/67
Camera 1 picture quality	N. G.	1/28/67
Camera 2	Poor	5/5/68 *
Camera 2 picture quality	Poor	5/5/68 *
Command tone A	Good	5/5/68 *
Command tone B	Good	4/30/68 *
Digital solar-aspect indicator	Intermittent	5/5/68 *
Housekeeping T/M commutators	Good	5/5/68 *
QOMAC coils	Good	5/1/68 *

*Date last used
†E-4 APT operational satellite launched 1/26/67
**Horizon-crossing indicator
***Magnetic attitude spin control
****Magnetic bias control

Group 2

1. Test spinup rockets for thrust and for response to digital command.

2. Investigate camera triggering at high and low spin rates.

Group 3

1. Roll spacecraft to extreme gamma angles (up to 110 degrees) to check thermal response, solar-array output, and cameras.

2. Roll spacecraft to low gamma angles (down to 0 degrees) to check thermal response, solar-array output, and cameras.

3. During these maneuvers, examine sun interference in the sensors.

Group 4

1. Reduce battery power below regulation level; observe spacecraft performance, and exercise Hi-Charge to recover power.

2. Switch cameras with full power on.

3. Switch regulators with full power on.

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GROUP I TESTS

1. <u>Spacecraft Receiver Degradation Test</u>

   A. Purpose: To determine if either of the two receivers on the spacecraft has changed in sensitivity during the time in orbit

   B. Procedure:

   - First test receiver 1 in a long low-elevation pass by taking enable-tone A telemetries every 30 seconds.

     The CDA* station shall report transmitter power (use 250w), antenna gain, line losses etc., to determine radiated power. Compare telemetry automatic gain control (AGC) levels with those obtained during launch checkout.

   - Repeat with receiver 2 using enable-tone B.

   C. Results: While checking the spacecraft receivers for possible degradation, the CDA station maintained a constant transmitter power of 250 watts and obtained a number of telemetries throughout the pass from acquisition of signal to loss of signal (AOS to LOS). This test used both tone-pair A and tone-pair B. (Varying signal strength to the spacecraft would be a function of the slant range.)

   This test indicated no receiver degradation during the lifetime of the spacecraft; in each case, if the AGC was out of clamp, a solid confirm was returned. The lower level could not be precisely determined because of the normal fluctuations of signal strength and the fact that, if the spacecraft did not receive a valid command, it did not respond with a telemetry of its receiver AGC. Within the bounds of the information thus available, both receivers are operating as well now as they did when launched.

2. <u>Pictures in Spacecraft Darkness Test</u>

   A. Purpose: To determine the aging of both cameras by measuring the black and the white video levels when the spacecraft is in darkness (earth also dark) and spacecraft in sun (earth still dark)

   This test also is a limited check on light leakage through the shutter.

*Command and data-acquisition

B. Procedure:

- Choose an orbit in which the spacecraft is in darkness over WALOMS* (an ascending-node pass). Program a picture sequence on the previous orbit to alarm over WALOMS. If possible, the spacecraft should come into sunlight during the picture sequence. Therefore, pictures can be obtained with spacecraft darkness/earth darkness and spacecraft sunlight/earth darkness conditions.

- Record telemetry before, during, and after all pictures.

- Turn on the digital solar-aspect indicator (DSAI) during the spacecraft transition from darkness to sunlight. The first reading of DSAI will give an accurate fix on spacecraft-illumination time.

C. Results: Pictures were taken with both cameras while the spacecraft was looking at a dark earth, and travelling from darkness to sunlight. The purpose of this test was to compare data with those obtained during launch checkout.

Camera 1 (Figure 1) has had a failure in the shutter board, and the black level in camera 2 (Figure 2) is now so high that usable contrast is gone. The loss of contrast due to aging appears as an increase in the black level, resulting in less range between black and white. Analysis of the pictures revealed two things:

1) The banding or venetian-blind effect caused by the spacecraft spinning in a magnetic field while reading out pictures was still present, at the same magnitude seen during launch checkout. This banding is a condition that has already been evaluated, and a fix has been made by the spacecraft contractor on ESSA 6. Our tests merely confirmed that no changes in magnitude have occurred on ESSA 4.

2) The true "black level" of a black earth is so close to that of the fiducial marks that it is difficult to pick out the difference in either the facsimile picture or on A-scans. The black level of the fiducials is a valid criterion of what the actual black level of the picture would be if in fact the spacecraft were seeing a black subject in its picture area. This is very useful to TEC, as the black level in an A-scan through the center fiducial is used as a criterion for the performance quality of the camera. The reticle, as the only black available in the working area of a normal picture, is a standard for monitoring the degradation of an APT** camera (Figures 3 and 4).

*Designation of Wallops Island CDA
**Automatic picture transmission

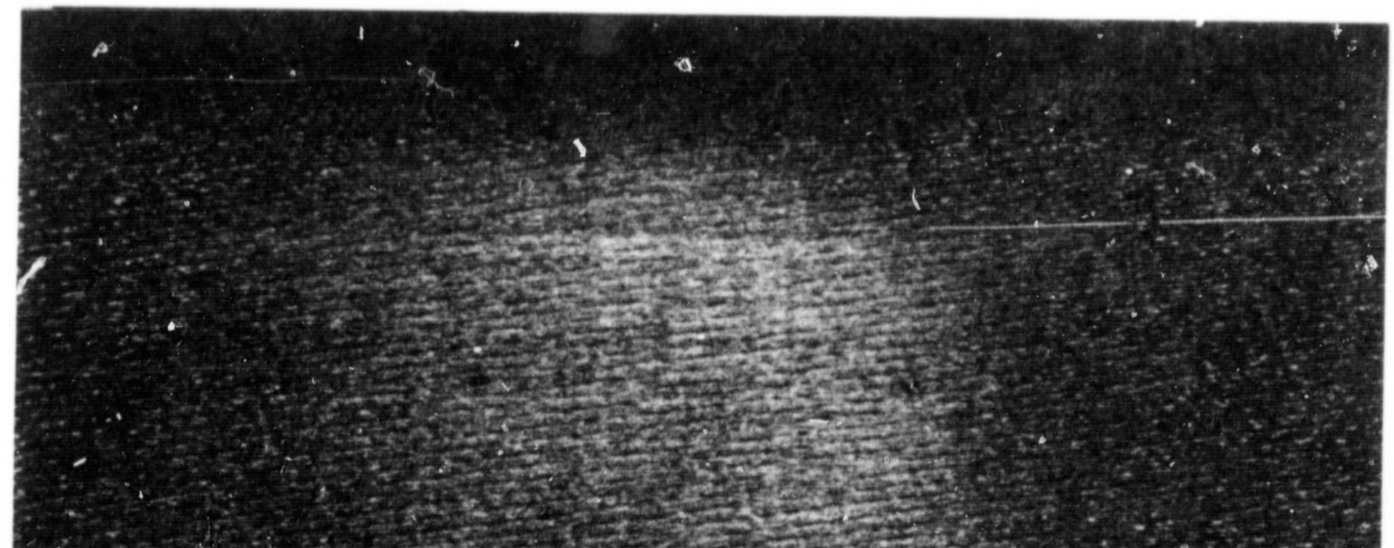

Figure 1. Spacecraft in Darkness, Camera 1

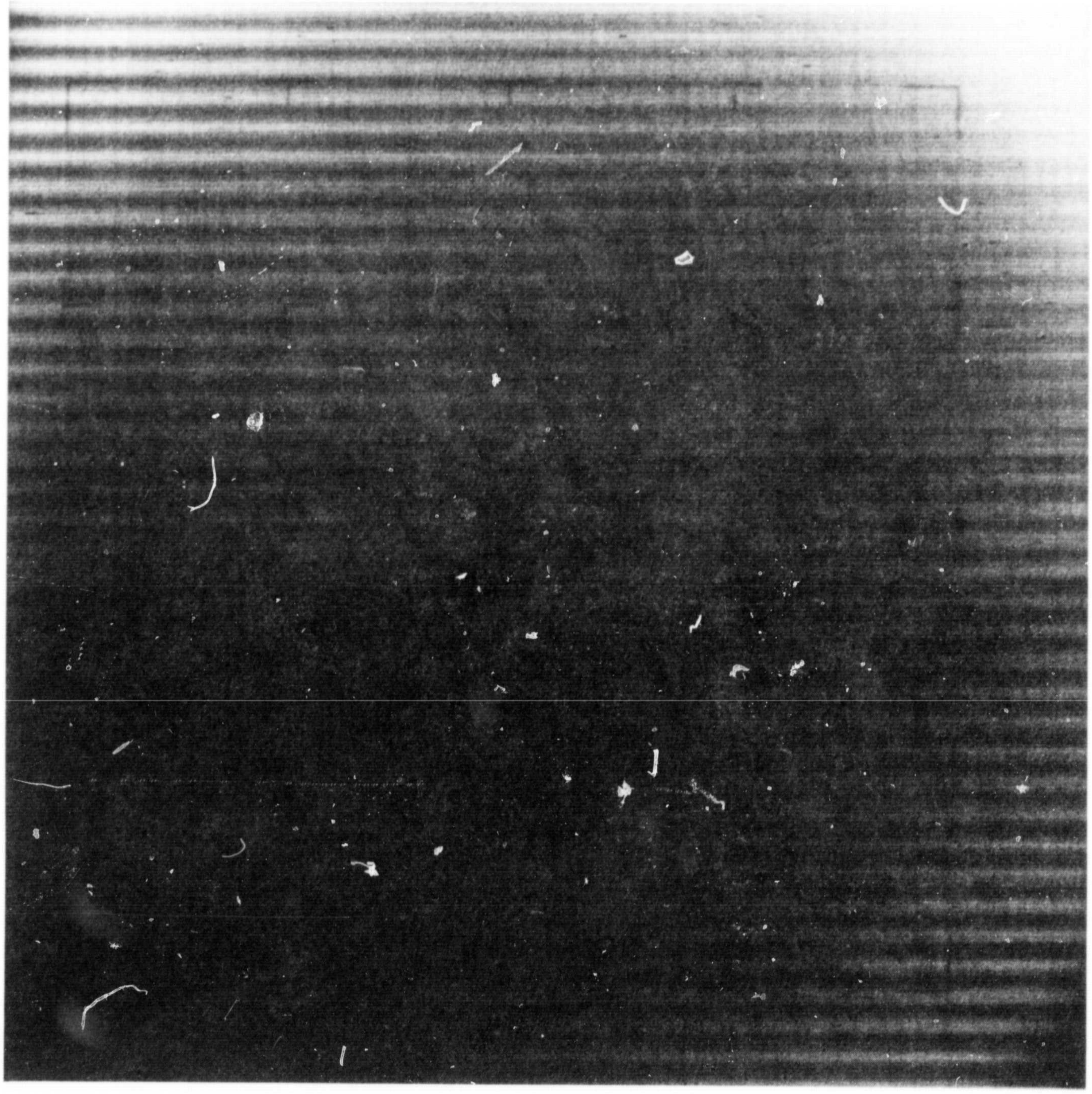

Figure 2. Spacecraft in Darkness, Camera 2

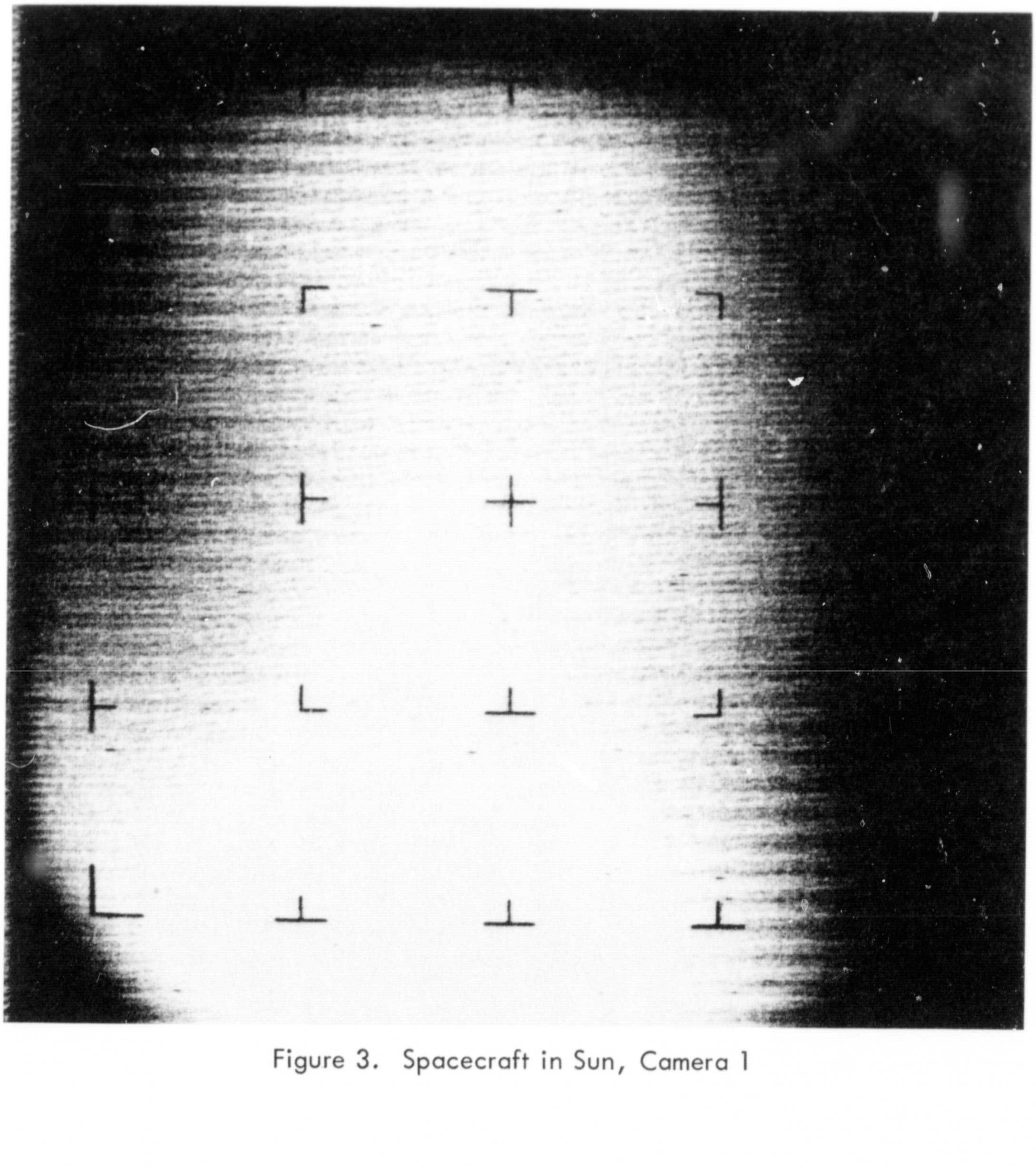

Figure 3. Spacecraft in Sun, Camera 1

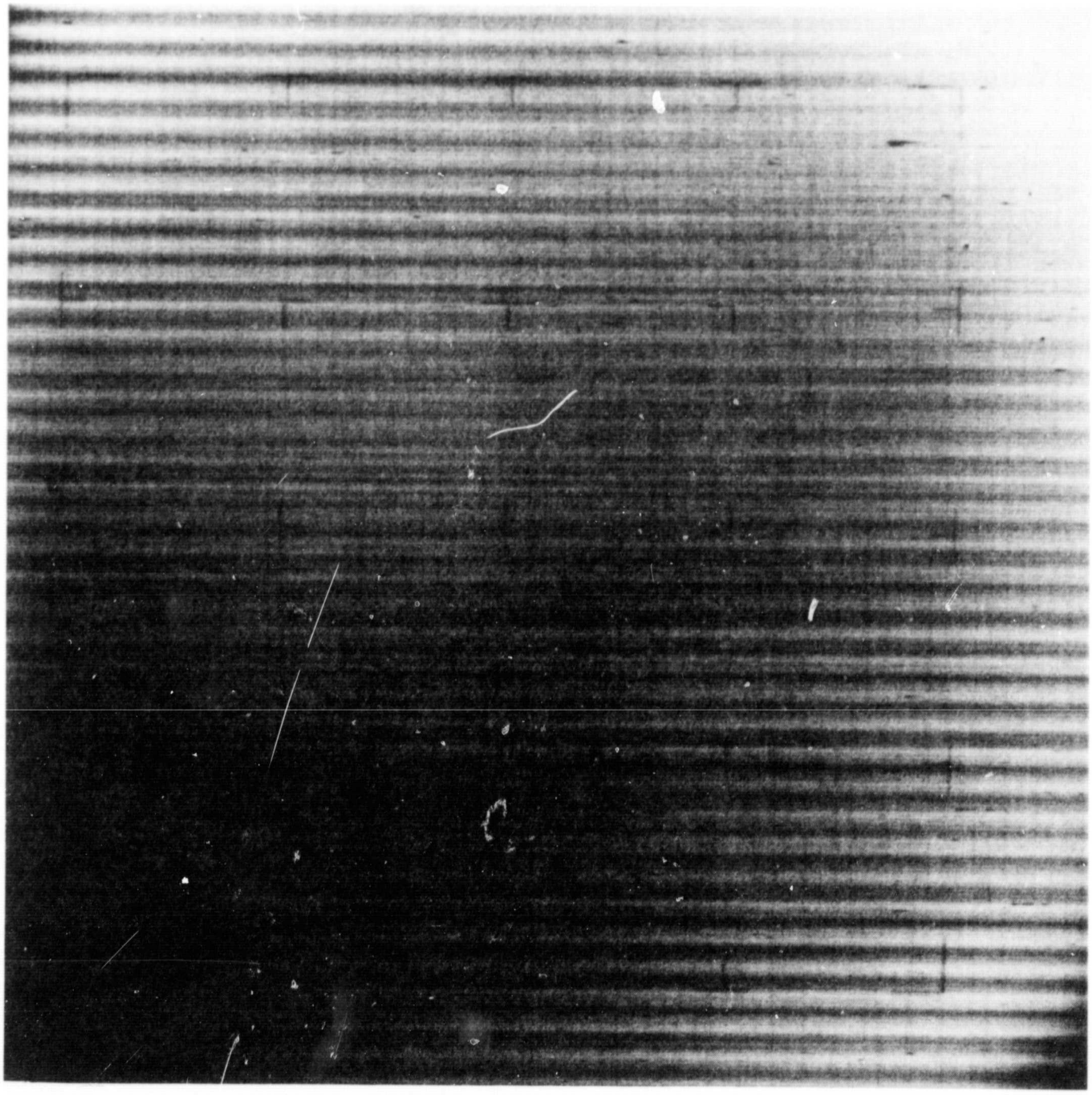

Figure 4. Spacecraft in Sun, Camera 2

3. Command-System Vulnerability Test

A. Purpose: The command system in the spacecraft (receiver and decoder) will be subjected to abnormal signals and commands in an attempt to get a "bad" command into the spacecraft. Jamming will probably occur, but the spacecraft should act on no "bad" or improper commands.

B. Procedure:

- Require both CDA's to transmit digital commands to the spacecraft at the same time: One CDA will transmit a "Request Telemetry" command; the other will transmit "DSAI ON."

- Have one CDA transmit a valid message (such as "Request Telemetry") while the other at the same time transmits a message with all "1"'s. This will check to see if an extra "1" can be inserted in a valid message by noise, etc.

C. Results: On February 1, 1968, during revolution 4701, both the Wallops and Gilmore CDA stations commanded the spacecraft at the same time. Both CDA's used command tone-pair A and transmitted digital commands. Figures 5 and 6 are samples of the responses. Some narrow "0" bits and some narrow sync bits were received as indicated in Figure 5. Once an extra "1" bit was obtained in an address; Figure 6 shows the readout of this incident. The spacecraft accepted no invalid commands when both CDA stations were transmitting, although an address or command could be made invalid and consequently rejected by the spacecraft. However, a remote word might possibly be altered by "jamming" and still be accepted by the spacecraft, because the 2-out-of-12 parity check does not apply to the remote word; however, CDA error sensing normally prevents transmission of an invalid remote word.

When one station uses tone-pair A and the other station uses tone-pair B, neither station can command the spacecraft or receive a confirm signal back. This test was performed during revolution 4714.

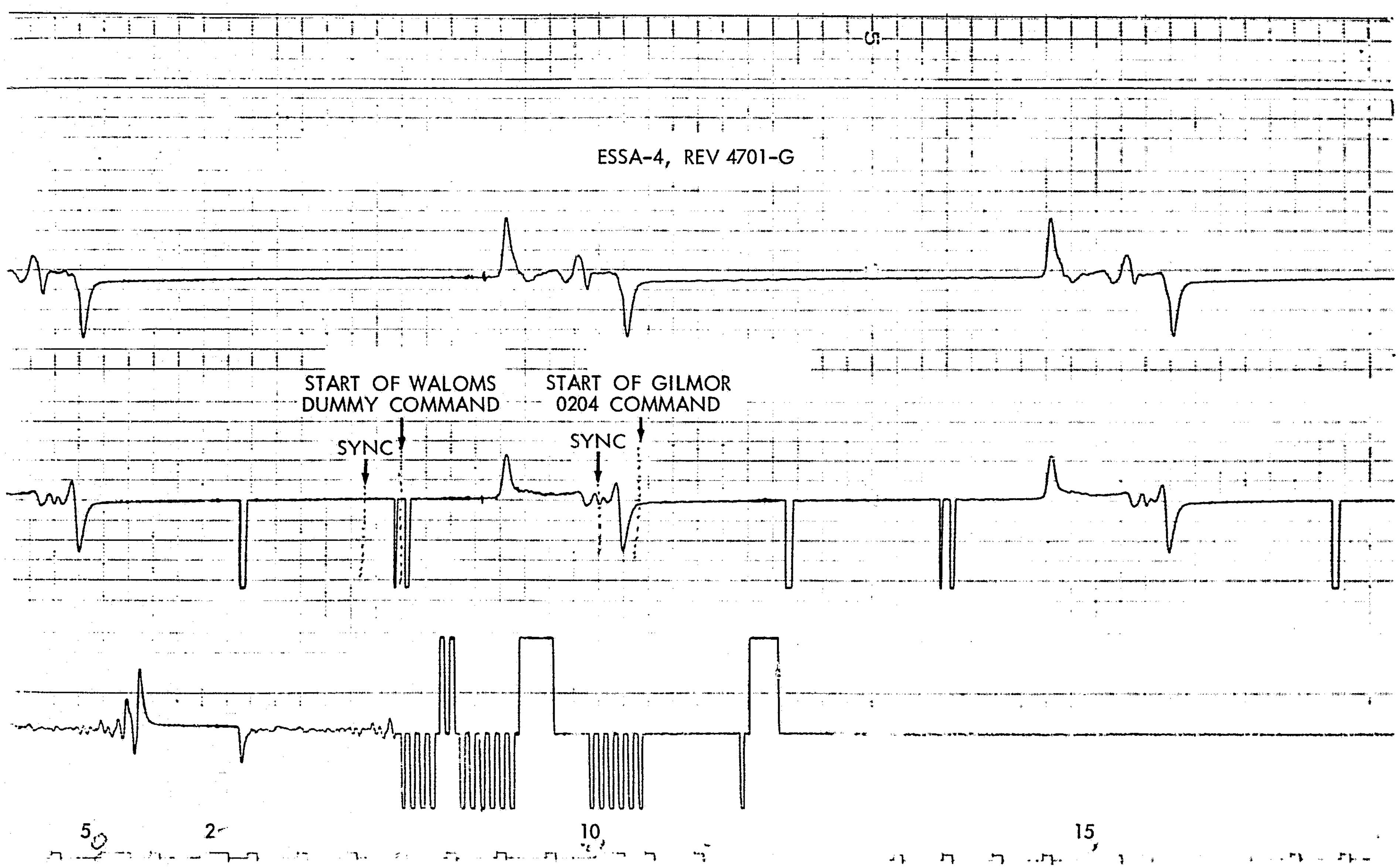

Figure 5. Simultaneous Commands to Spacecraft

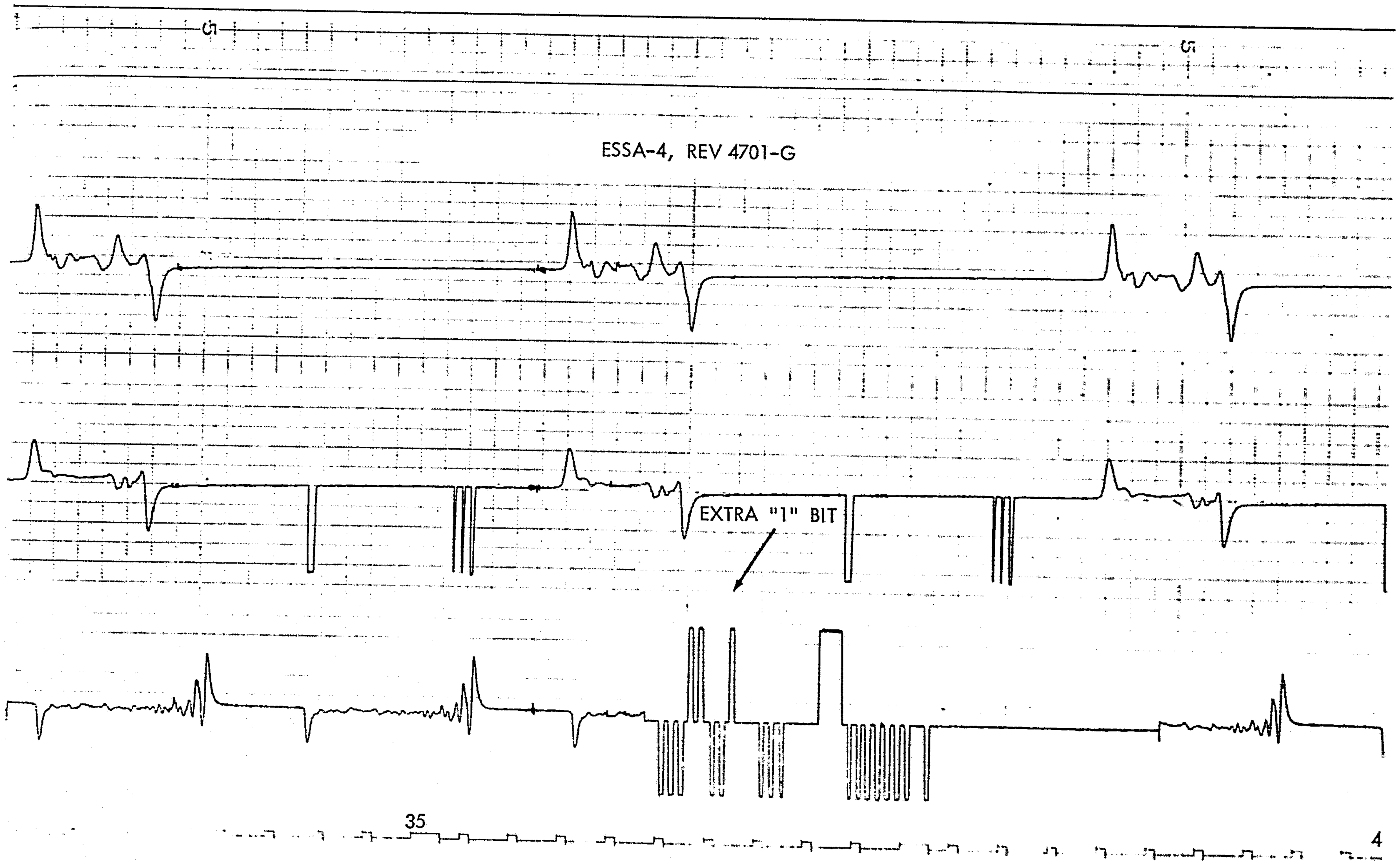

Figure 6. Invalidation of Order by Simultaneous Command

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GROUP II TESTS

A. Tests

1. Test command of spinup rockets, and check amount of thrust from one pair of rockets.

2. Investigate camera triggering at high and low spin rates.

B. Purpose

1. To test the operation of the spinup rocket command. The "Fire Spinup" command has never been tested on a TOS spacecraft in orbit.

2. To determine the amount of spinup obtained from the thrust of one rocket pair

3. To test camera-triggering operation at the higher spin rate. The spacecraft spin rate will be slowed down later using the MASC system. The nominal spin rate on ESSA 4 need not be maintained because normal pictures are no longer being taken.

4. To test camera-triggering operation at lower than normal spin rates

C. Procedure

1. Choose an ordinary orbit for exercising the spinup rocket command; follow the program procedure described in the programmer's manual to fire one pair of spin rockets. Note and record the amount of spinup: an increase of approximately 3.5 rpm is expected.

2. Set in a camera program sequence and test it over a CDA, preferably in earth sunlight, during a long acquisition pass. A dummy plus two pictures are desired. Use the "good" camera (camera 2) and observe pictures for possible horizons. Monitor the timing between frames, picture alarm, etc., to observe triggering.

3. Select a later orbit or orbits to spin down the spacecraft to a point where camera triggering can be tested closer to the nominal spin window. The efficiency of the MASC system at high and low spin rates can also be observed.

4. Continue despin until a rate of approximately 5.567 seconds is reached. Program another picture sequence over a CDA as before to observe mistriggering.

5. Return spin rate to normal limits of 5.475 to 5.525 seconds.

D. Results

The Group II tests investigated the performance of the spacecraft in relation to its spin rate.

The spin period of the spacecraft was allowed to delay to 5.738 seconds (10.45 rpm) and a picture sequence was commanded. The resulting pictures showed the earth's horizon in the southern half of each picture (as a result of the backup shutter pulse which triggers the camera). Whenever 5.5666 seconds elapse without a horizon-crossing indicator (HCI) pulse, the backup camera-trigger pulse is generated in the spacecraft programmer. The spacecraft had 0.172 second to spin before the camera would look straight down and the HCI field-of-view would intersect the horizon, generating the normal HCI pulse for camera triggering. The 8-channel Brush analog recording showed the backup pulse occurring approximately 0.2 second before the HCI pulse. This was received on revolution 5049-W (Figures 7 and 8).

On revolution 5050-W, the four-picture sequence alarmed over the station again and the spinup rocket command was sent during the dummy frame. The command was successful, and resulted in a spin period of 4.367 seconds (or, a spin rate of 13.73 rpm). Therefore, the first pair of rockets increased the spin rate by 3.28 rpm.

The fast spin rate caused inhibition of the first good frame by the dummy frame readout. Because the 41 spins occurred before the end of the 200-second dummy readout, a long hold period intervened before the start of what should have been the second picture. The time between the second and third pictures was also shortened, as expected; both these pictures were taken when the camera was looking into space. This is also caused by the generation of a backup spin (HCI) trigger if the HCI pulse occurs too early. The function of this backup triggering is given in the I & O* Handbook, Vol. 1, p. 2-54, through 2-59.

*Instruction and Operating

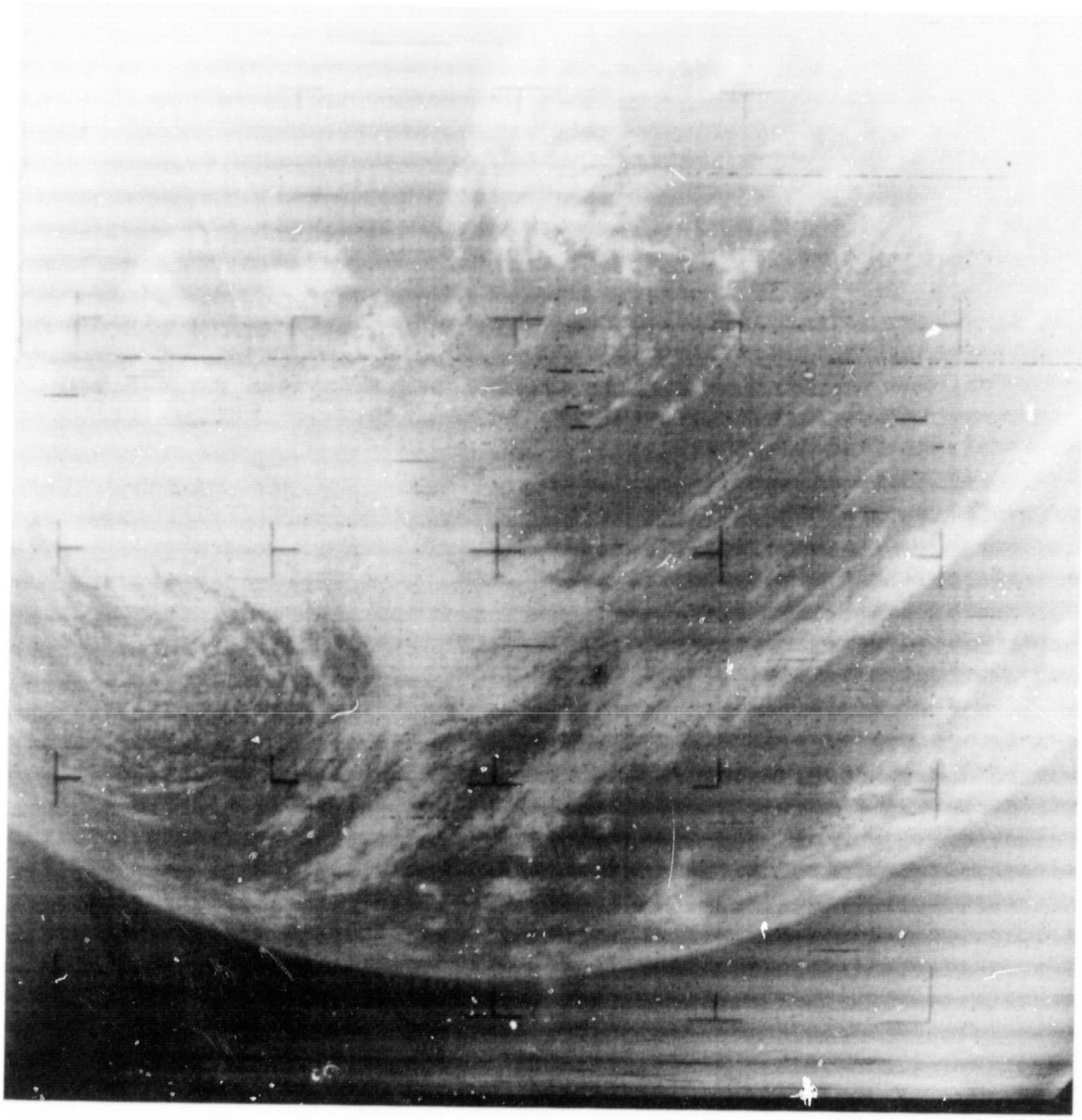


Figure 7. Spacecraft at High Roll Angle, Picture 1

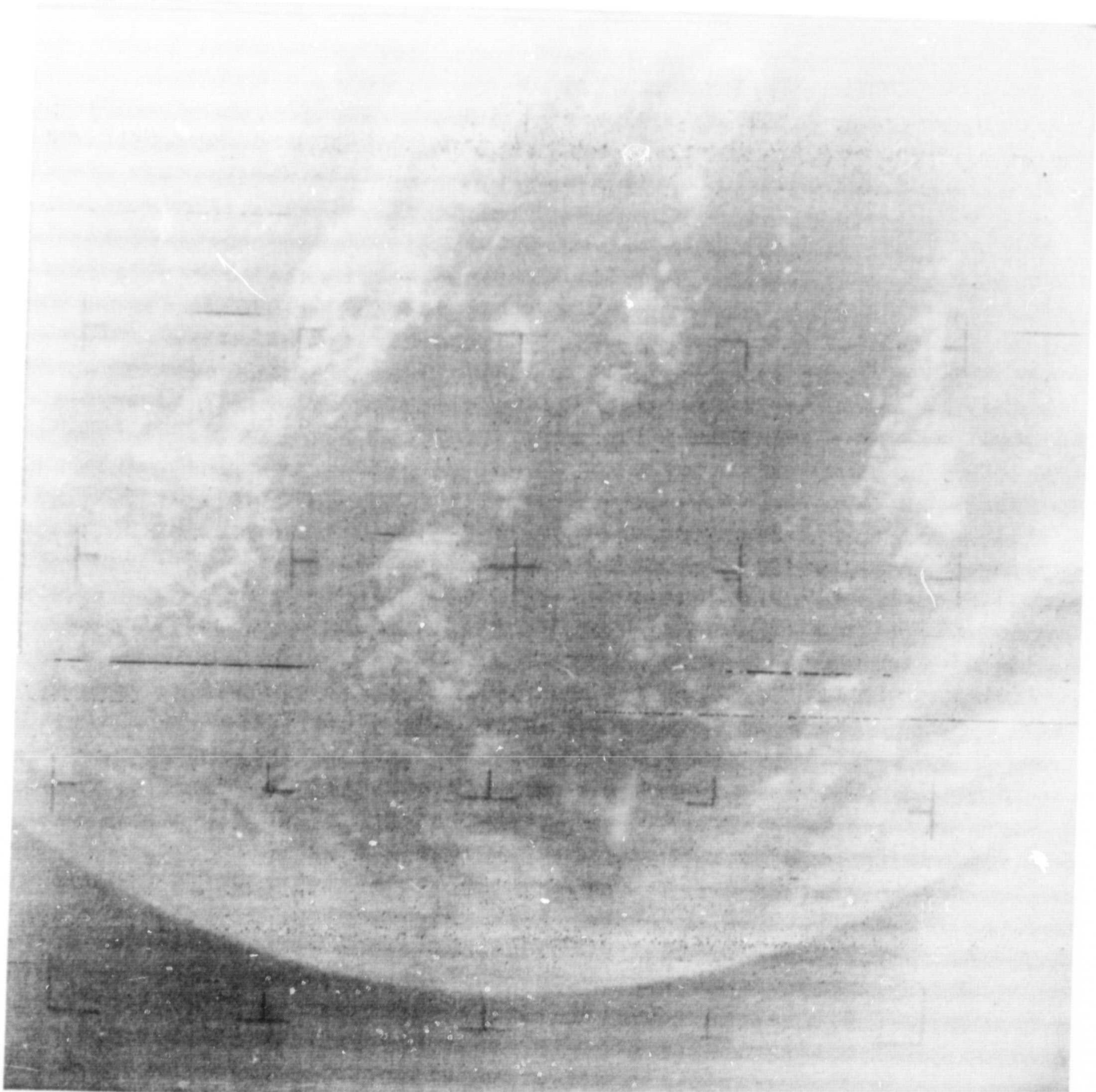


Figure 8. Spacecraft at High Roll Angle, Picture 2

GROUP III TESTS

A. Tests

1. Roll spacecraft out to extreme gamma angles (up to 110 degrees) to evaluate spacecraft thermal response, solar-array output, and cameras.

2. Roll spacecraft down to low gamma angles (down to zero degrees) to evaluate spacecraft thermal response, solar-array output, and cameras.

3. Examine performance of the horizon-crossing indicator (HCI) and the attitude/horizon indicator (AHI), including sun interference, during these extreme roll maneuvers.

B. Purpose

1. To evaluate spacecraft performance at extreme gamma angles in order to determine spacecraft deterioration, operating limitations, and thermal response (comparison with published thermal data), and to obtain data for emergencies that may arise during launch turnaround.

2. To examine camera performance at high and low temperatures (although APT cameras are temperature-compensated, other peculiarities may occur).

3. To observe and examine sensor performance at high roll angles and with respect to sun interference.

C. Procedure

1. Increase spacecraft roll to a gamma of 110 degrees in 50-degree increments. Record spacecraft performance and temperatures. Program a four-picture sequence using camera 2 over WALOMS when the spacecraft is at 90-degree gamma. Choose λ' (lambda = the point at which maximum roll occurs in an orbit) so that minimum roll occurs over WALOMS for picture-taking purposes.

   Generally, about two orbits per day are available for command of ESSA 4. Therefore, each day, a QOMAC program can be set in to accomplish 5 degrees of additional roll per day.

After attaining 110-degree gamma, try another four-picture sequence over WALOMS. The temperatures should have increased to somewhat more favorable levels than at 90-degree gamma. If the battery voltages are low as a result of poor illumination angle of the solar-array side panels, use the Hi-Charge mode during the picture sequence.

After the tests at 110-degree gamma, return the spacecraft immediately to mission-mode attitude and gamma. The spacecraft is now at approximately 72-degree gamma in mission mode; sun time is approximately 70 percent.

2. In the next portion of this test, similar to the first, go down to zero-degree gamma in 10-degree steps per day. The larger 10-degree steps are chosen because lower gamma angles mean less danger to the spacecraft, and some data in this region are already available from ESSA 5 and ESSA 2.

   Choose lambda' again so that minimum roll occurs over WALOMS for picture purposes. Program a four-picture sequence while the spacecraft is at zero-degree gamma. The sequence should be the same as the previous (program a four-picture sequence to alarm over the station; receive approximately two good frames; shut off programmer before loss of signal). Record telemetry before, during and after pictures.

   After the picture sequence at zero-degree gamma, return the spacecraft immediately to mission-mode orientation. This completes this phase of testing.

3. Follow the precautionary temperatures and voltages listed on page V-8, "APT Prelaunch Operational Analysis Handbook," September 15, 1967. Danger regions to be watched in the telemetry channels appear in "Alignment and Calibration Data for TOS-B Satellite," September 21, 1967.

4. Spacecraft should follow the applicable temperature charts of "Mission Mode Orientation and Thermal Response of TOS/AVCS* Spacecraft," September 21, 1967.

D. Results

Group 3 tests on ESSA 4 took place from April 1 to April 12, 1968, to examine the operation of the spacecraft at extreme gamma angles. Figures 9, 10, and 11 show spacecraft attitude during these tests.

*Advanced vidicon–camera system

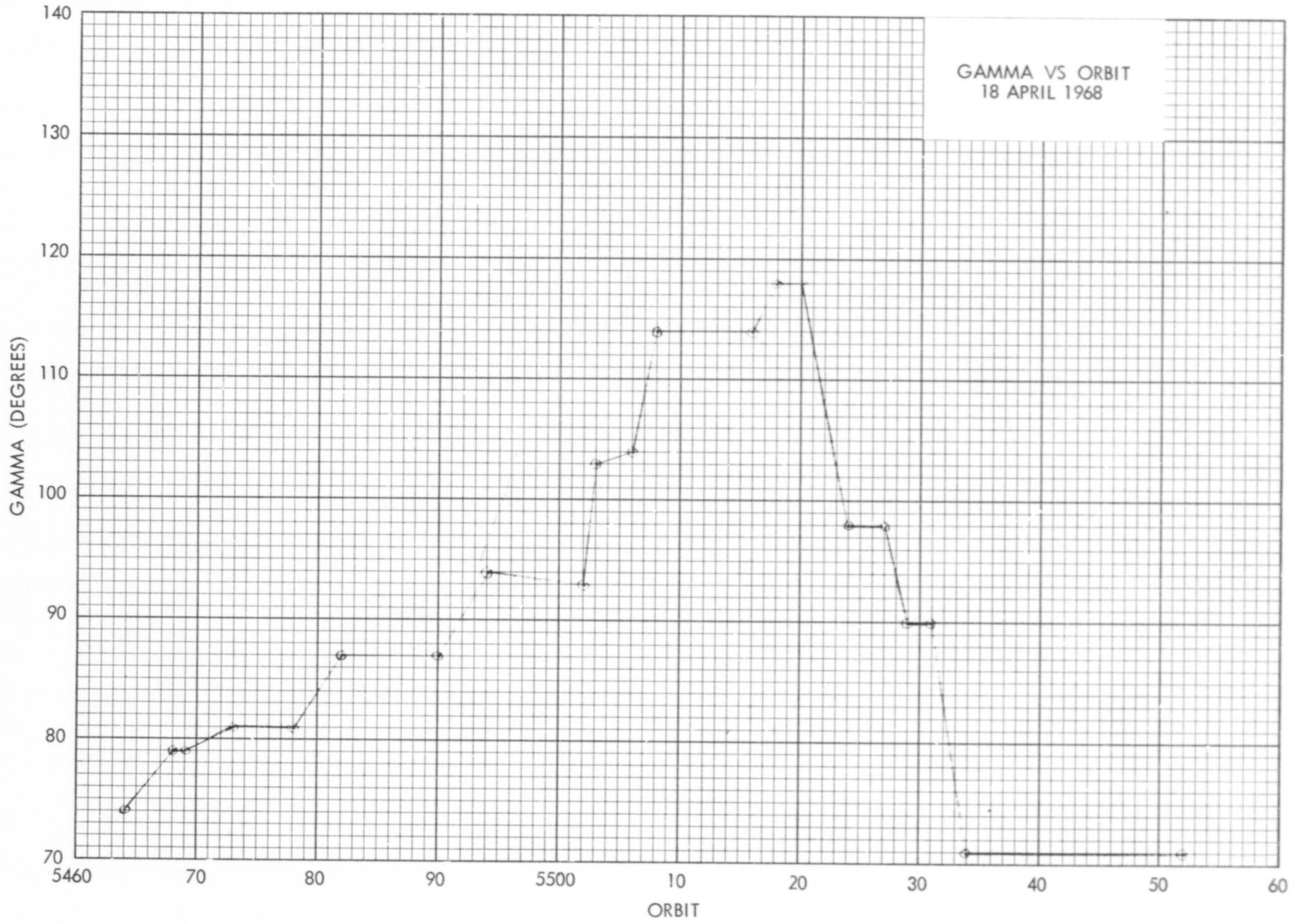


Figure 9. Gamma Angle vs Orbit (5464 - 5552)

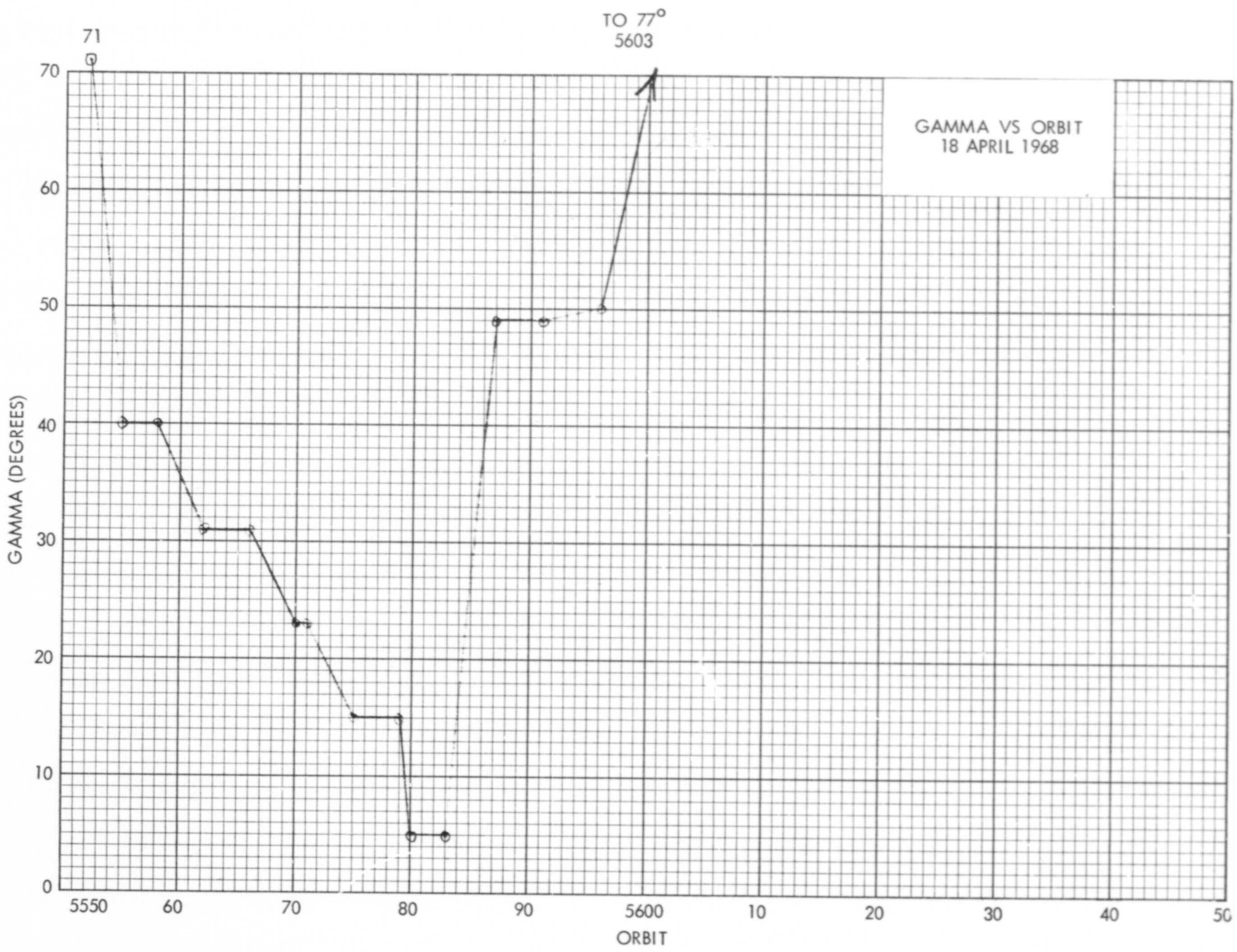


Figure 10. Gamma Angle vs Orbit (5552 - 5603)

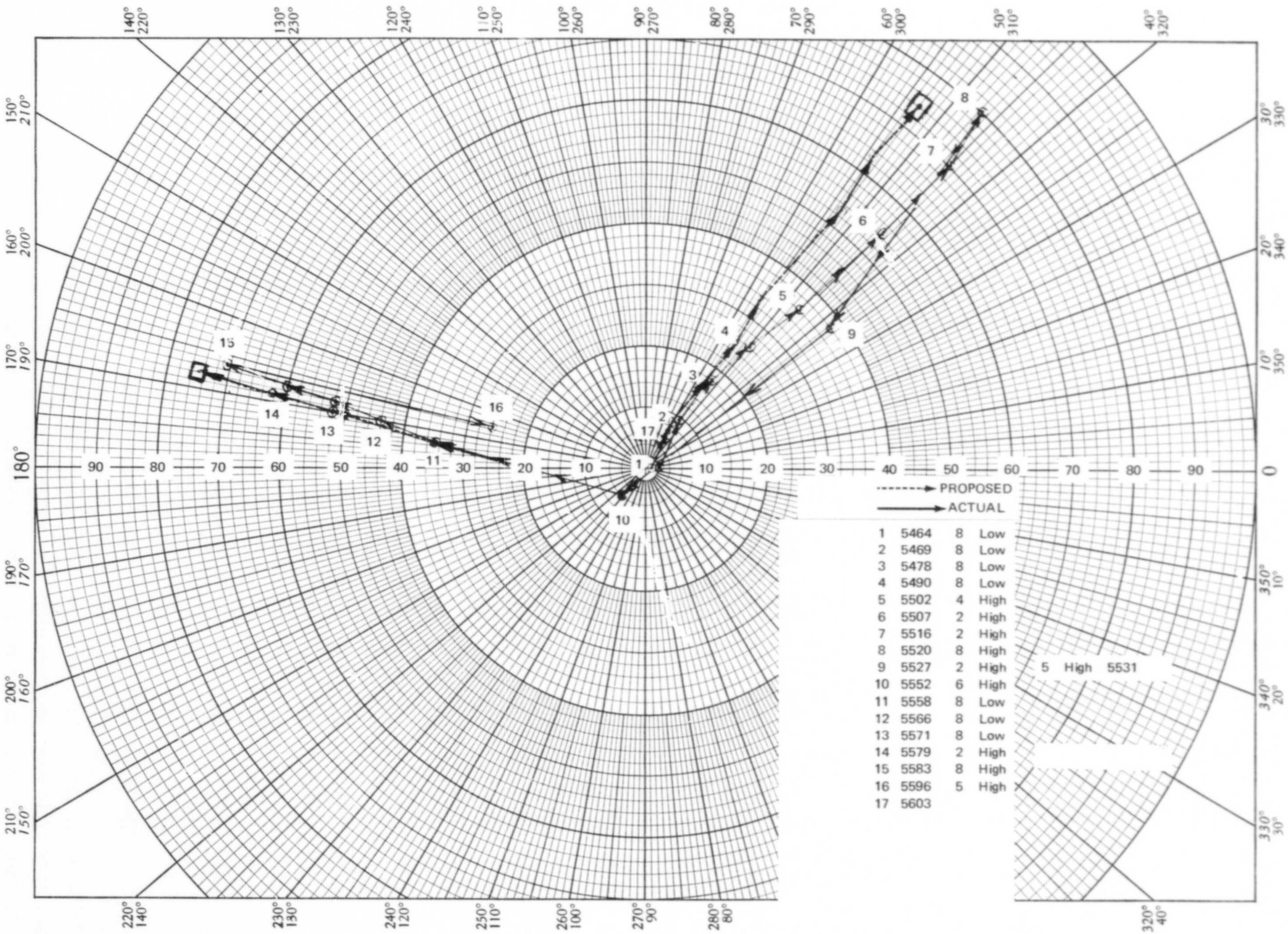


Figure 11. Attitude Plot of QOMAC Cycles

(The term gamma angle used in this report means the angle between the spin axis and the sun, measured from the top-hat end. For example, zero-degree gamma means the sun on the top hat only; 90-degree gamma would be the sun in line with the rim of the spacecraft.)

The first series of tests was to roll the spacecraft to gamma angles up to 118 degrees in order to duplicate the predicted temperature profiles given in the manual "Mission Mode and Thermal Response of TOS/APT and TOS/AVCS Spacecraft," AED-M 2143, September 21, 1967, Contract NAS 5-9034.

Conflicts of time and available orbits made it possible to look for only gross indications. A spacecraft not in constant sunlight never actually achieves a constant temperature equilibrium on its surface areas (Figure 12). In many instances, temperatures plotted were taken shortly after the spacecraft had just come out of darkness; in other instances, the spacecraft had just completed a series of high-torque QOMAC cycles, with resulting large changes in gamma. Both conditions produce sudden temperature changes. During this group of tests, the amount of sun time was approximately 70 percent.

Figures 13 through 17 show the temperature response of the batteries. Actual temperatures observed, plotted with predicted curves in these figures, appear slightly flatter than expected; this is probably the result of little or no stabilization time.

Baseplate temperatures (Figures 18 and 19) follow the predicted profile well, certainly within the excursions of Figure 12. This fact supports the theory that the batteries, with their interior position and large mass, would follow closely the predicted temperatures if given time to achieve equilibrium.

These figures, together with Figures 20 and 21, suggest that the temperature minima may occur at a gamma angle of 80 to 83 degrees rather than at the 90 degrees predicted by the mission-mode and thermal-response manual. Considering that the rib structure of the baseplate is external and not normal to the sidewalls, this assumption is probably true. This fact may influence operational considerations for spacecraft that operate in near-high-noon angles (where normal mission-mode orientation of the spacecraft would result in gamma angles around 90 degrees).

Sidewall temperatures (Figure 20) show the extreme excursions predicted in Figure 12: the magnitudes and slopes of these excusions are too large for meaningful evaluation. Temperatures of the top hat (Figure 21) did not follow the predicted profile nor, apparently, the broad violent excusions of Figure 12, probably because the top hat is in shadow when the spacecraft is at a gamma angle of greater than 90 degrees. In fact, top-hat temperatures dropped well below the telemetry-reduction curves in the calibration book for ESSA 4.

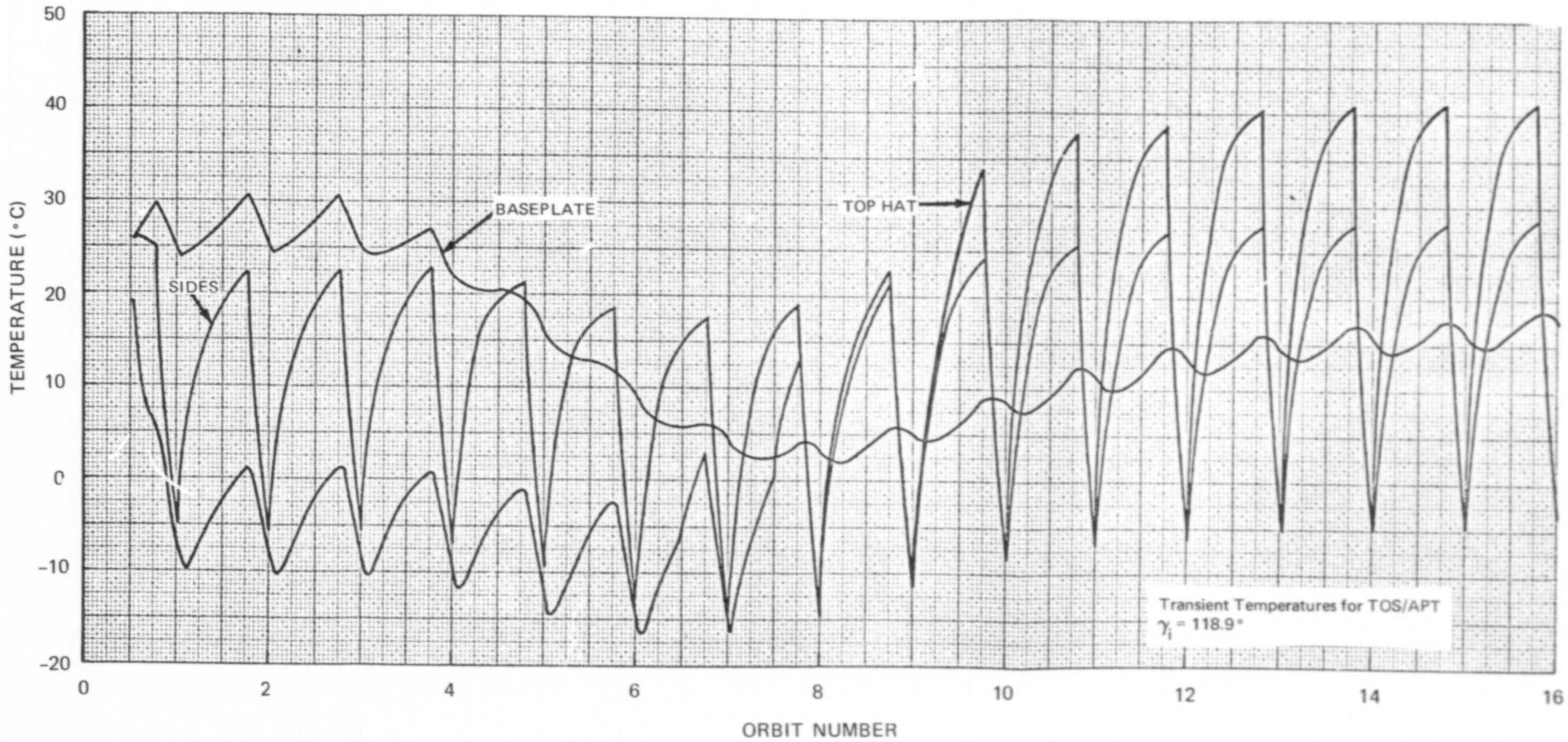
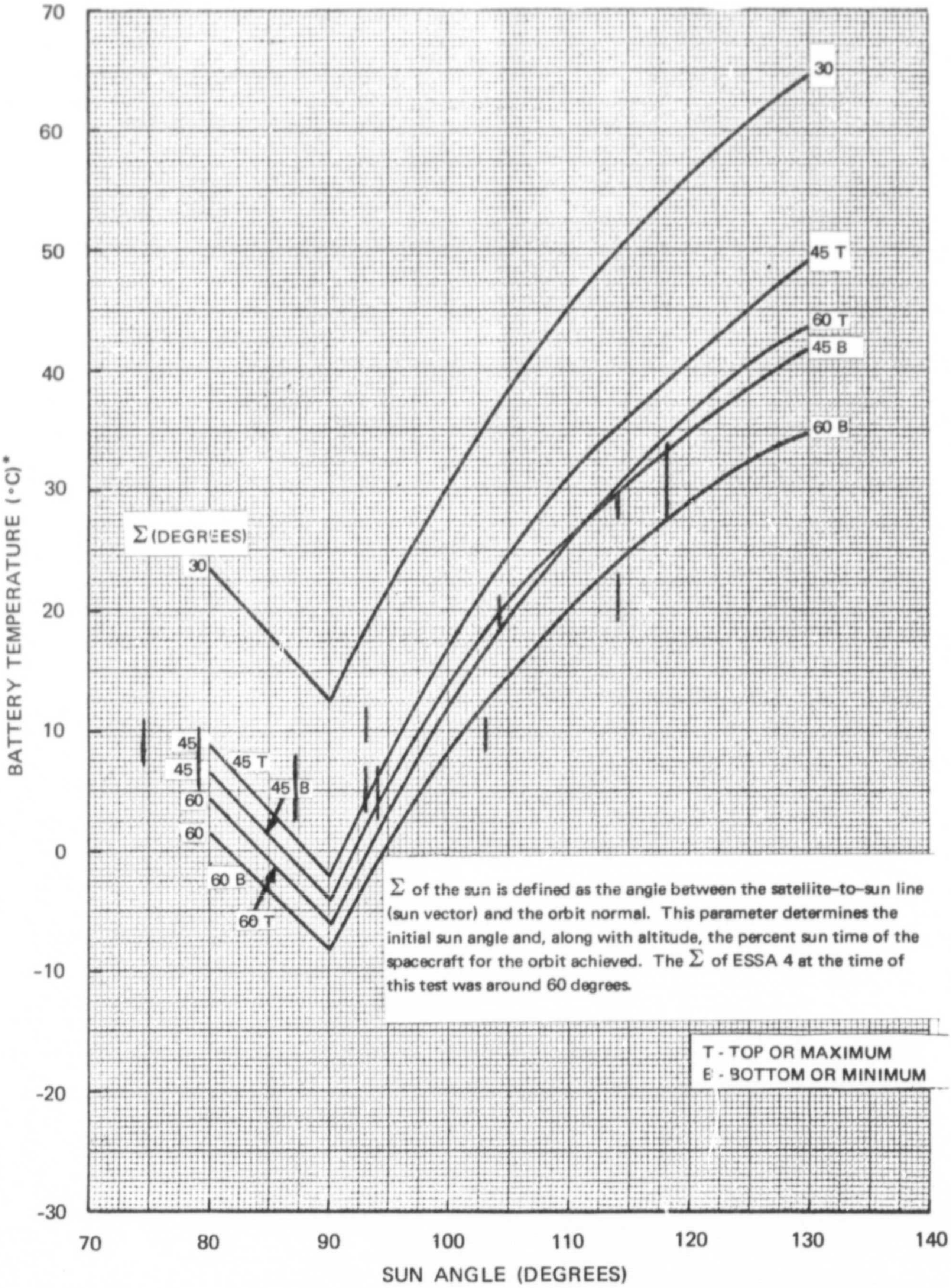


Figure 12. Transient Temperatures for TOS/APT Components



*Plot of battery temperature, with a continuous vertical line between lowest and highest average of the 3 batteries; all temperatures are the average of that battery, in all telemetries from that pass.

Figure 13. Dynamic Equilibrium and Steady-State Temperatures for TOS/APT Batteries (Average)

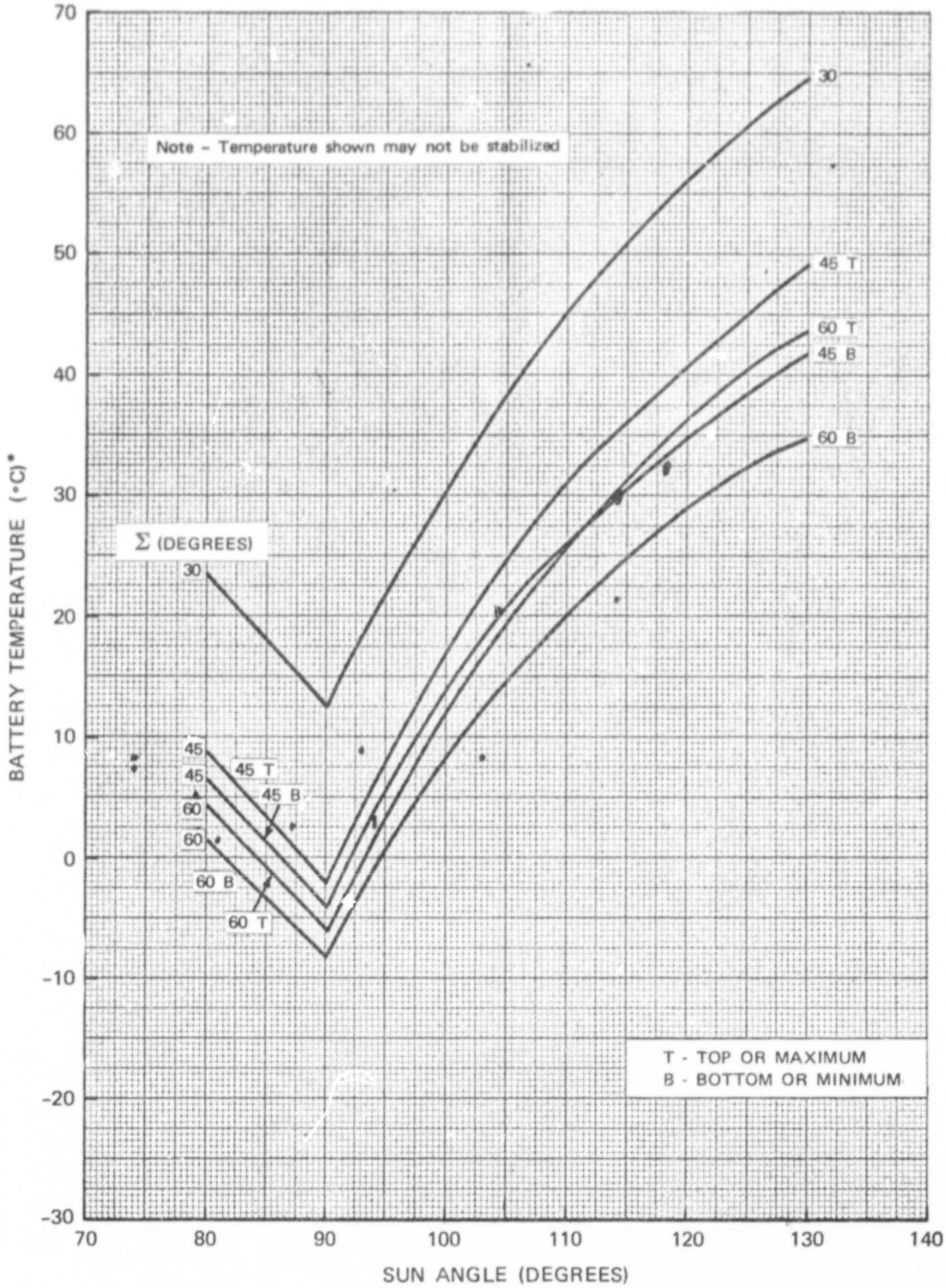
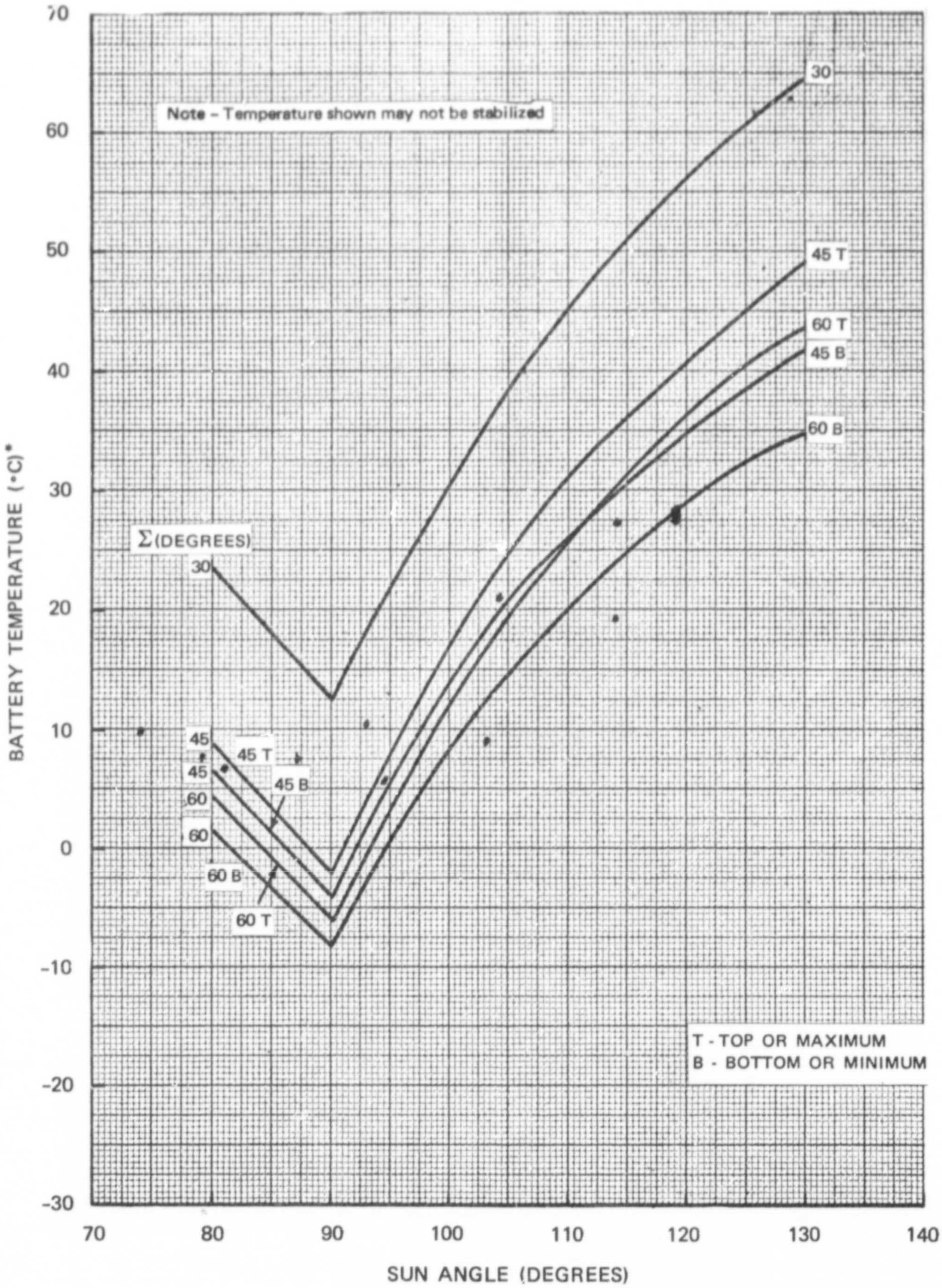


Figure 14. Dynamic Equilibrium and Steady-State Temperatures for TOS/APT Battery 1



*Average of all battery 2 telemetries received from each revolution

Figure 15. Dynamic Equilibrium and Steady-State Temperatures for TOS/APT Battery 2

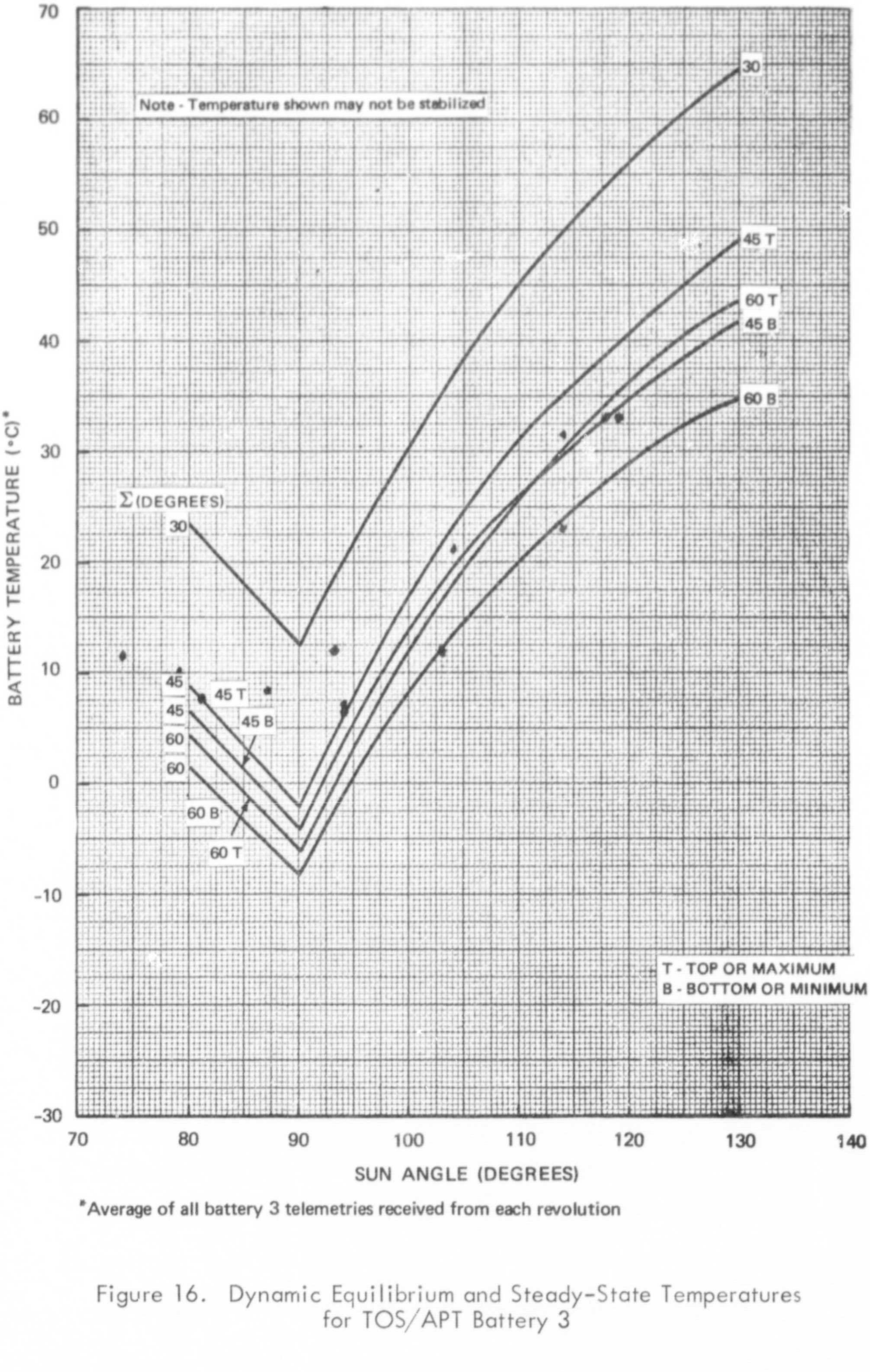


Figure 16. Dynamic Equilibrium and Steady-State Temperatures for TOS/APT Battery 3

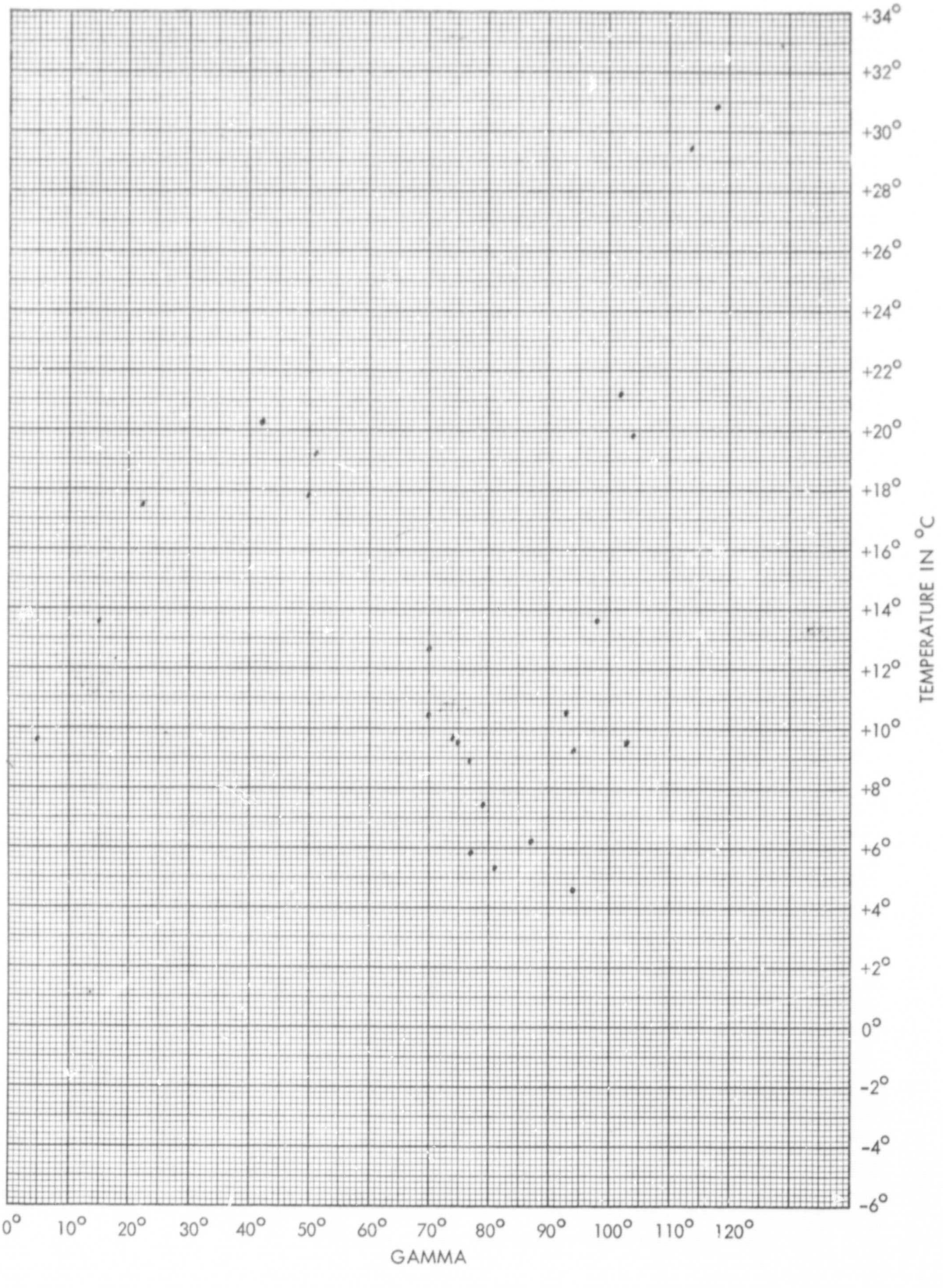
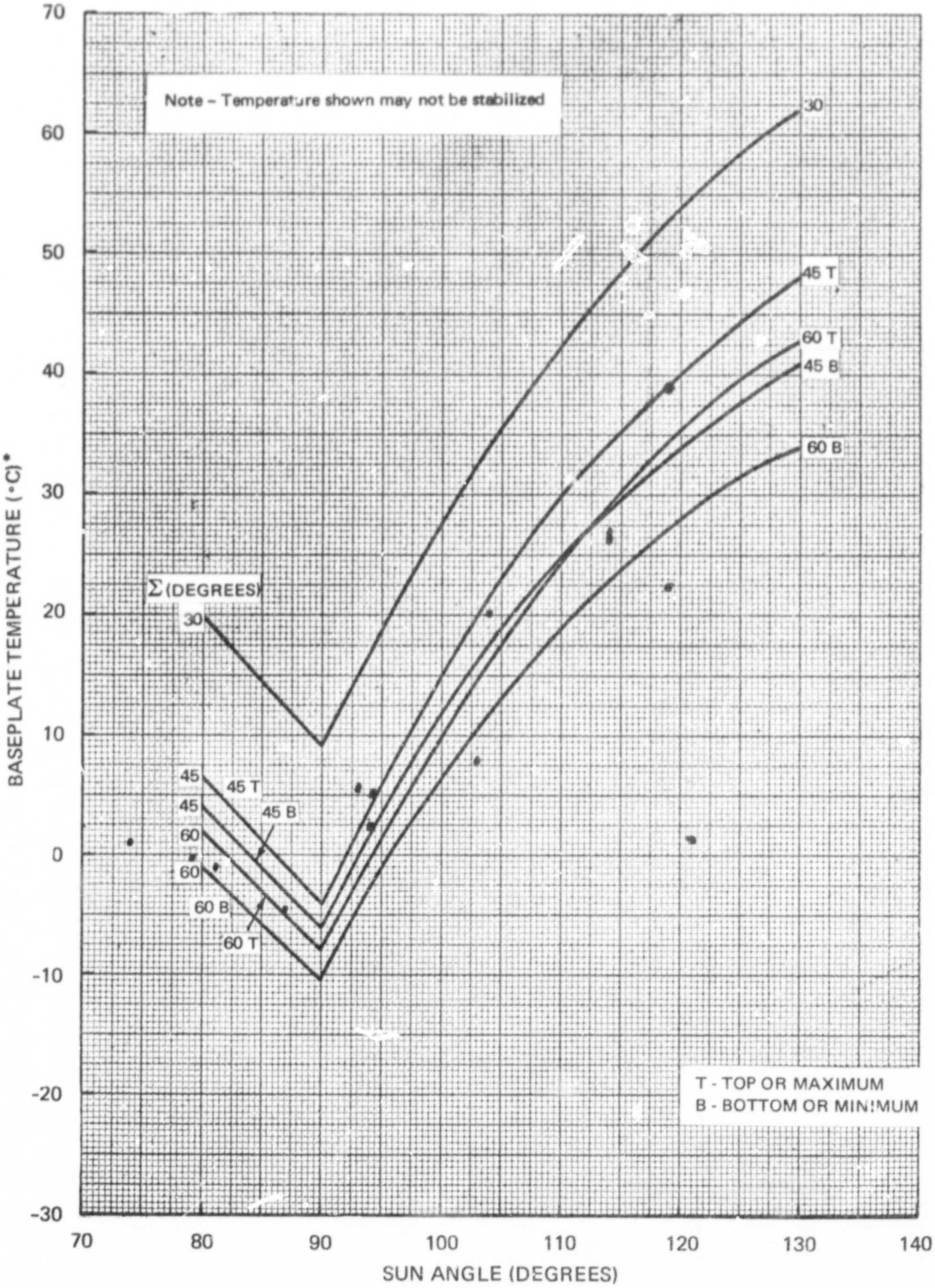


Figure 17. Average Battery Temperature vs Gamma



*Average of all telemetries received from each revolution

Figure 18. Dynamic Equilibrium and Steady-State Temperatures for TOS/APT Baseplate

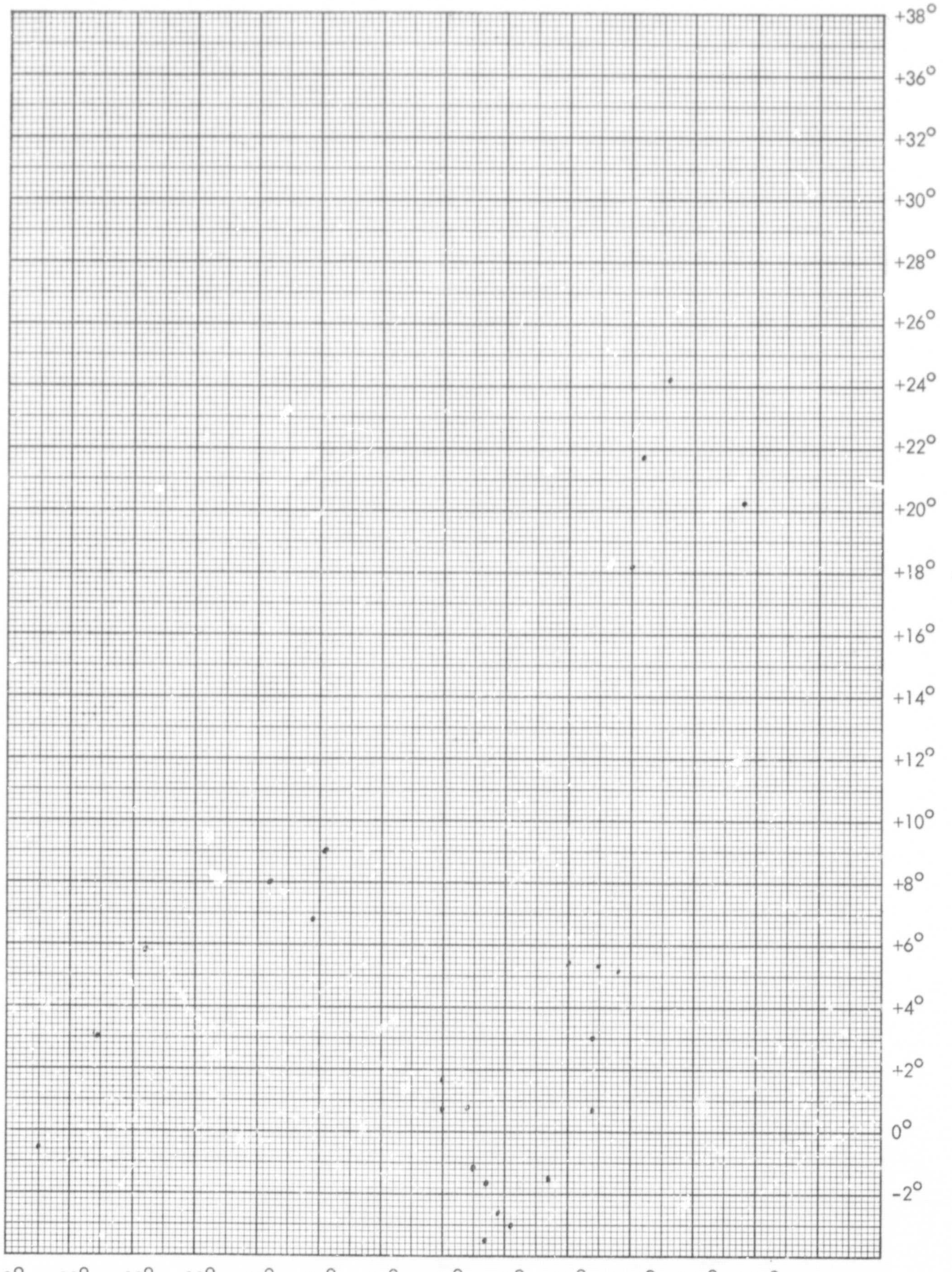
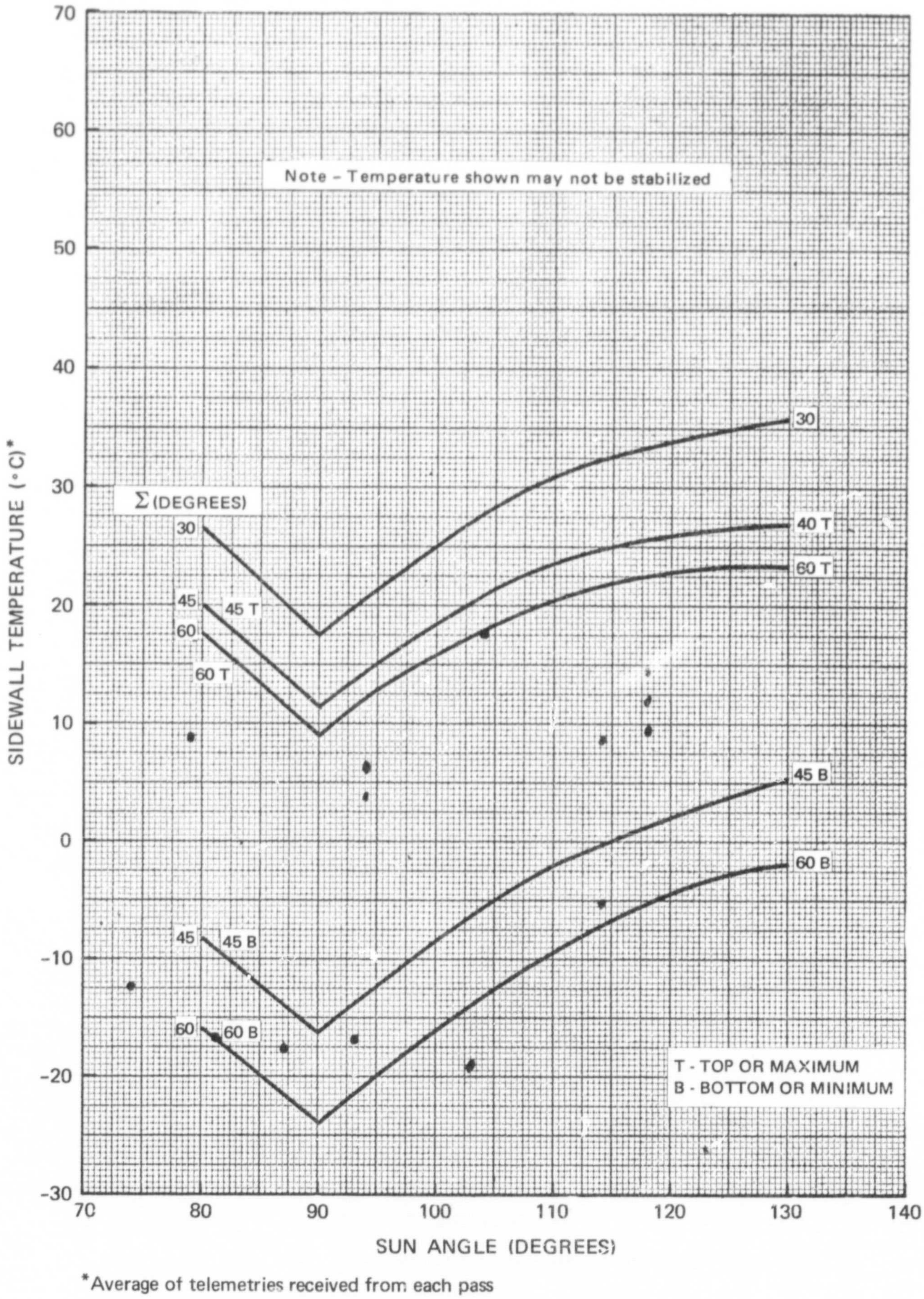
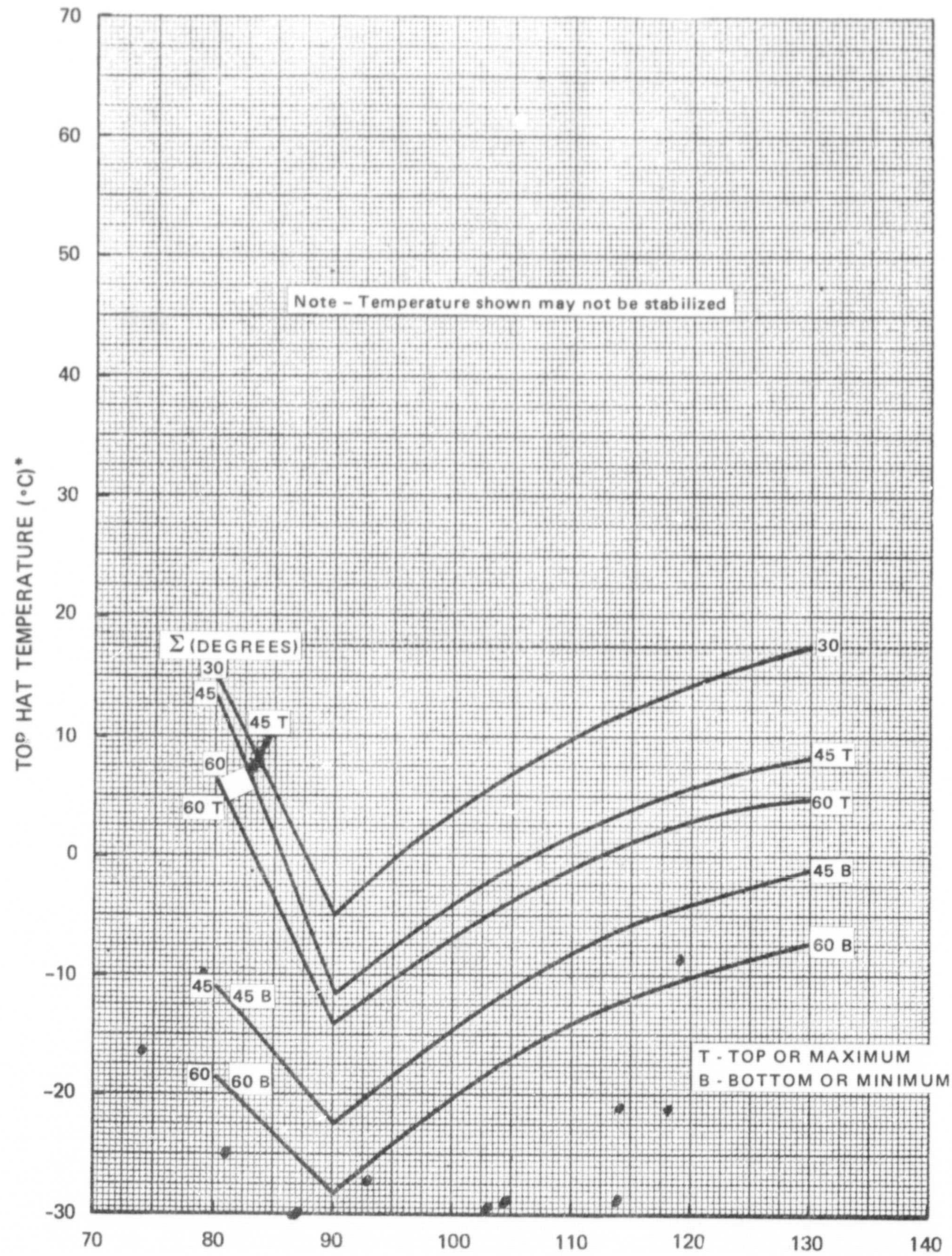


Figure 19. Baseplate Temperature vs Gamma



*Average of telemetries received from each pass

Figure 20. Dynamic Equilibrium and Steady-State Temperatures for TOS/APT Sidewalls



*Average of all telemetries received from each revolution

Figure 21. Dynamic Equilibrium and Steady-State Temperatures for TOS/APT Top Hat

Here again, because of the low mass of the structure in question, and the few telemetries available, the plots are not a smooth curve. Measurements obtained suggest that, under these conditions (gamma greater than 90 degrees), the top hat is running far cooler than predicted. Again, these plots suggest that—although the temperature minima may be considerably colder than expected—the stabilized temperature profile might well approximate the shape of the predicted curve more closely than these test plots indicate. In any case, minima for these tests are colder than had been expected.

Figures 22 through 25 show solar-array outputs plotted over a wide range of gamma. Note that these plots show up as two fairly distinct series of points: The lower values (zero) are telemetries taken as the spacecraft emerges from darkness over Gilmore; the higher level plots (+) are taken over Wallops later in the same revolution. The curves are unexpected. More reasonable plots appear in Figure 25, which represents telemetries from four random (over a day or two) 12-picture sequences by ESSA 3. Temperature and/or albedo effect on ESSA 4 may account for the fluctuations shown in the plots; the anomaly is not explainable at present.

Figure 24 shows that the optimum operational mode (from the power standpoint) is around 45-degree gamma. As the power available from a solar cell is essentially a cosine function, loss of efficiency by the sidewalls is compensated for by the increased output of the top hat, resulting in a reasonably constant power available at all gamma angles that are less than 45 degrees.

When ESSA 4 was at higher gamma angles, a new anomaly was observed in the readout of the digital solar-aspect indicator. On this spacecraft, the second DSAI bit has been a constant zero; however, during revolutions 5489, 5490, 5494, 5503, 5507, and 5508, the fourth bit also turned up a constant zero. On revolutions 5494 and 5503, this produced a reasonable reading, but an obvious error on the others. All these readings occurred when the gamma was greater than 84 degrees and the spacecraft was, as a result, quite cold. With the return of the gamma to lower values, the fourth bit again worked correctly; also, for the brief period when the spacecraft was left at gamma angles of more than 115 degrees (resulting in warmer temperatures), the fourth bit once more was working correctly. We infer from this that the DSAI circuitry has become temperature-sensitive, and that we can expect a failure of the fourth bit whenever the baseplate temperature drops below approximately 0° C. The high rate of temperature change during each orbit makes it impossible to pinpoint an exact temperature at which DSAI failure will occur; nor do we know whether this failure is related in any way to the failure of DSAI bit two, which also is always a zero.

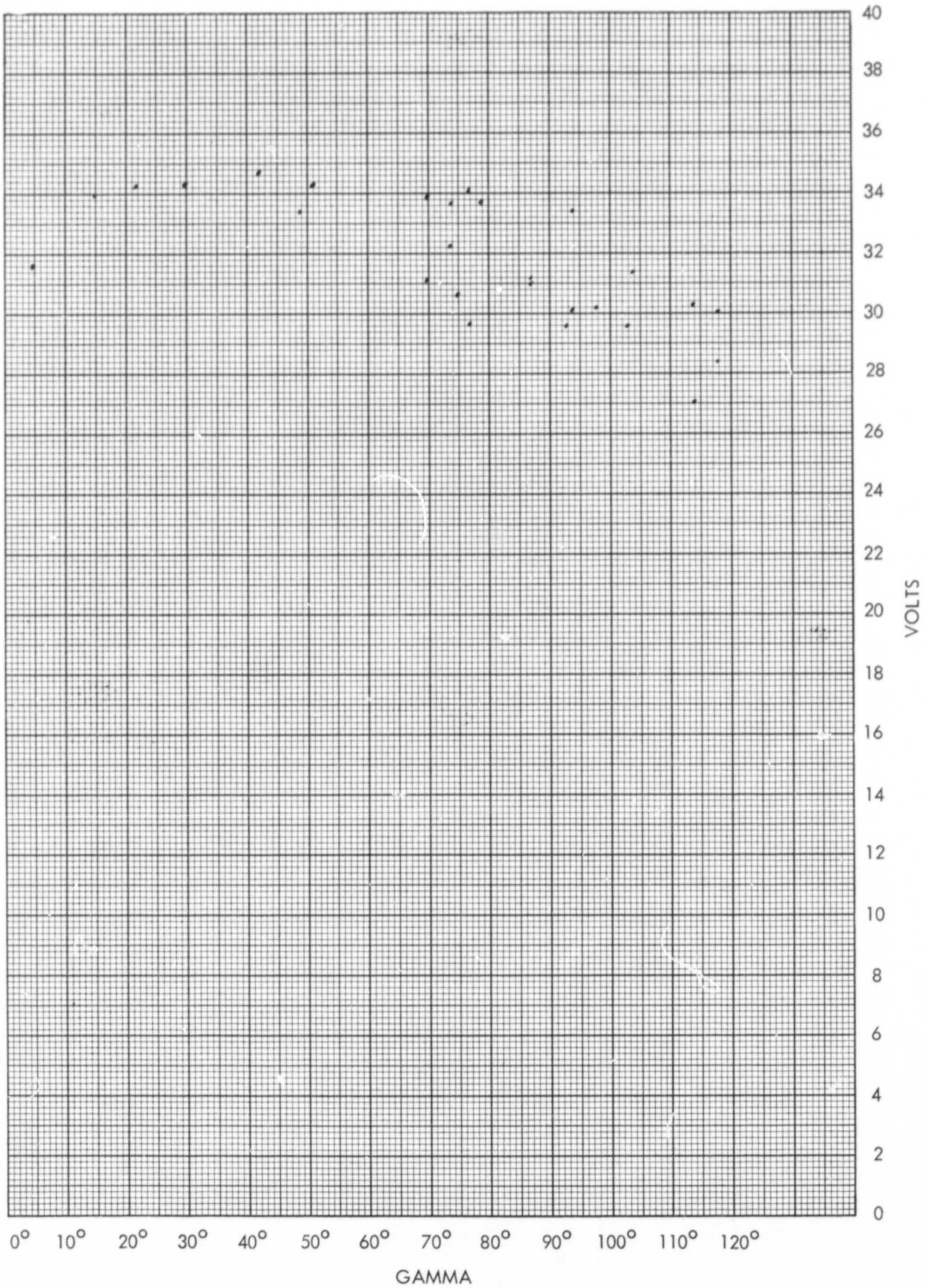


Figure 22. Array Voltage vs Gamma

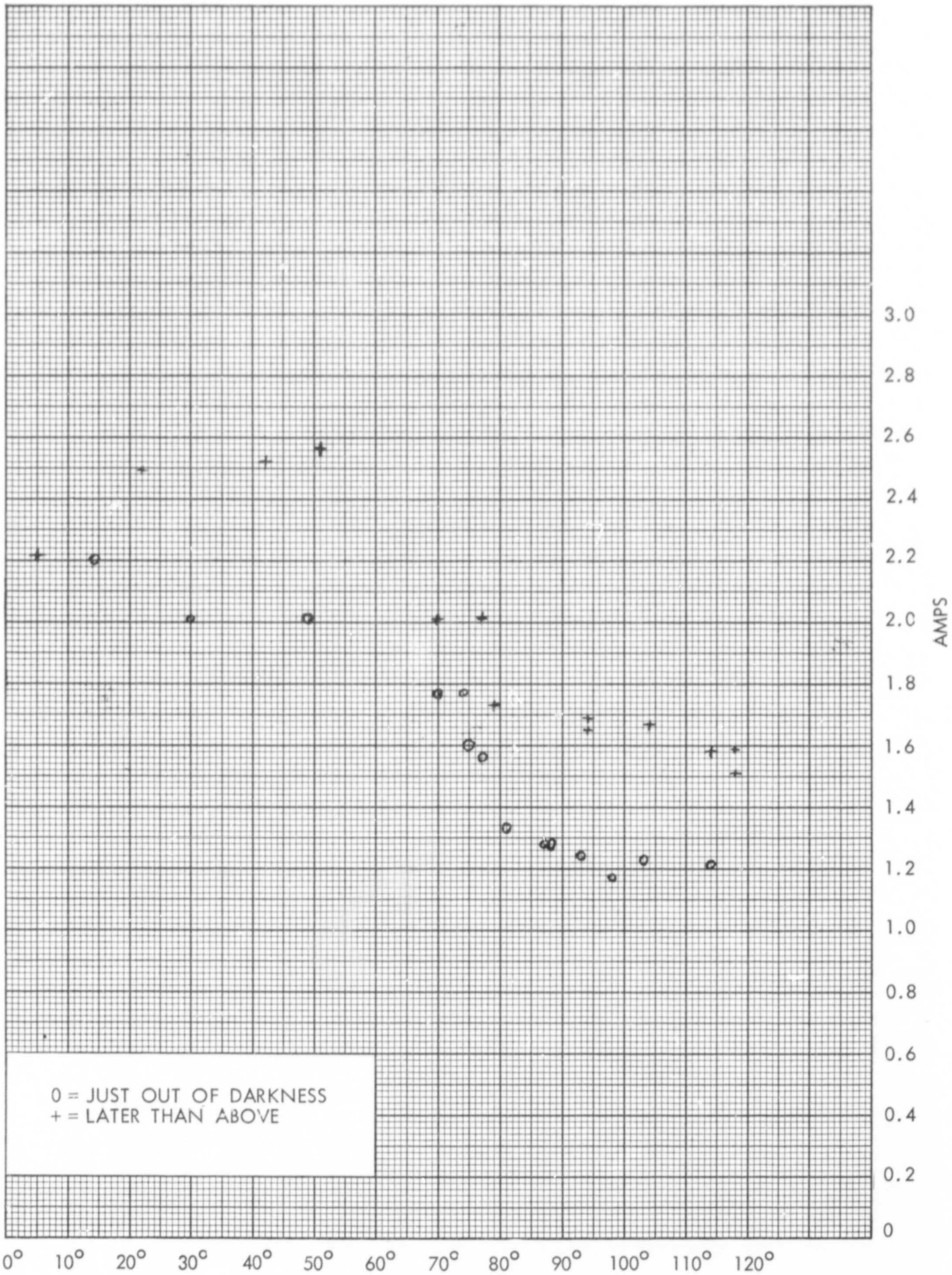


Figure 23. Array Current vs Gamma

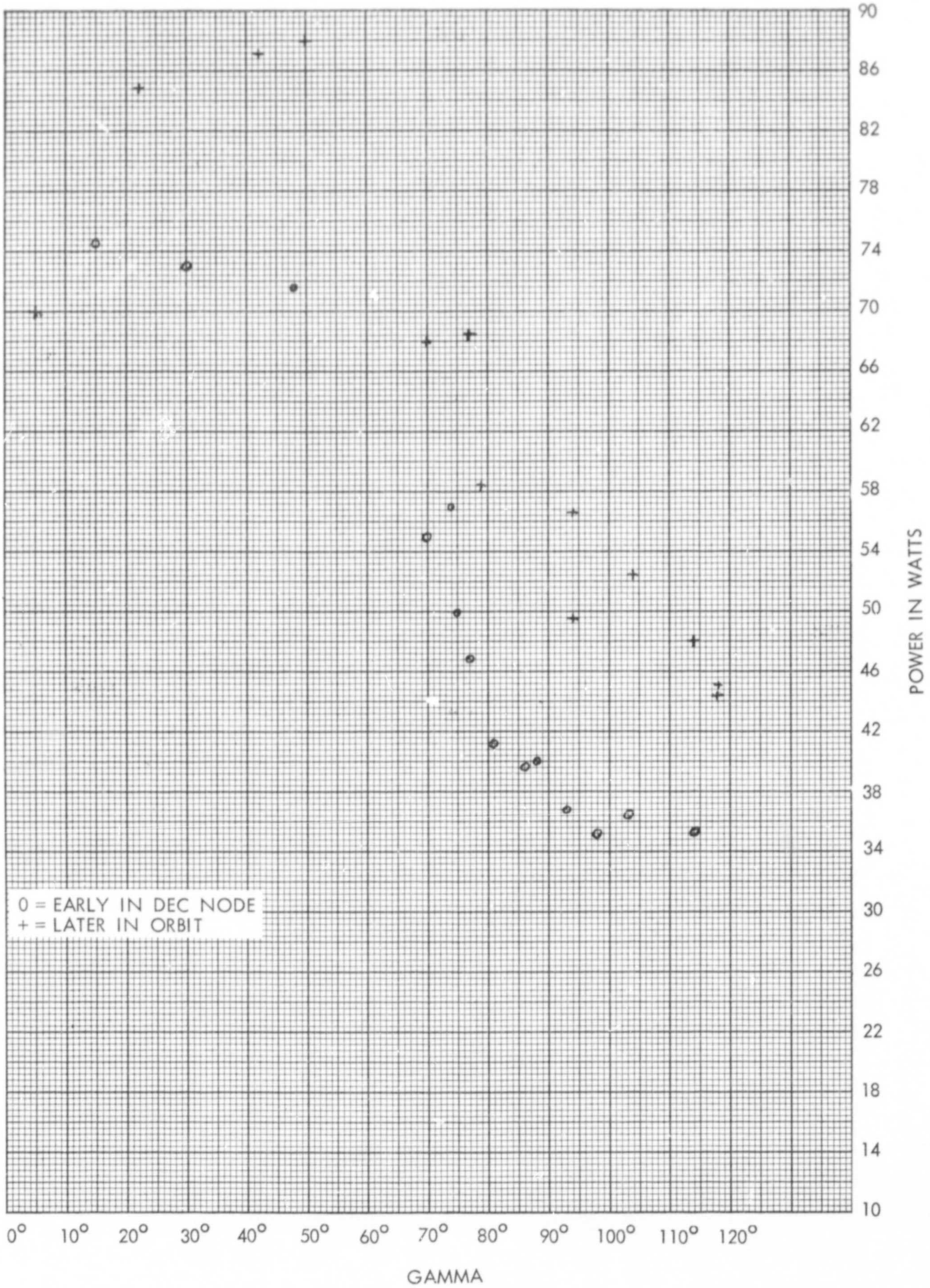


Figure 24. Array Power vs Gamma

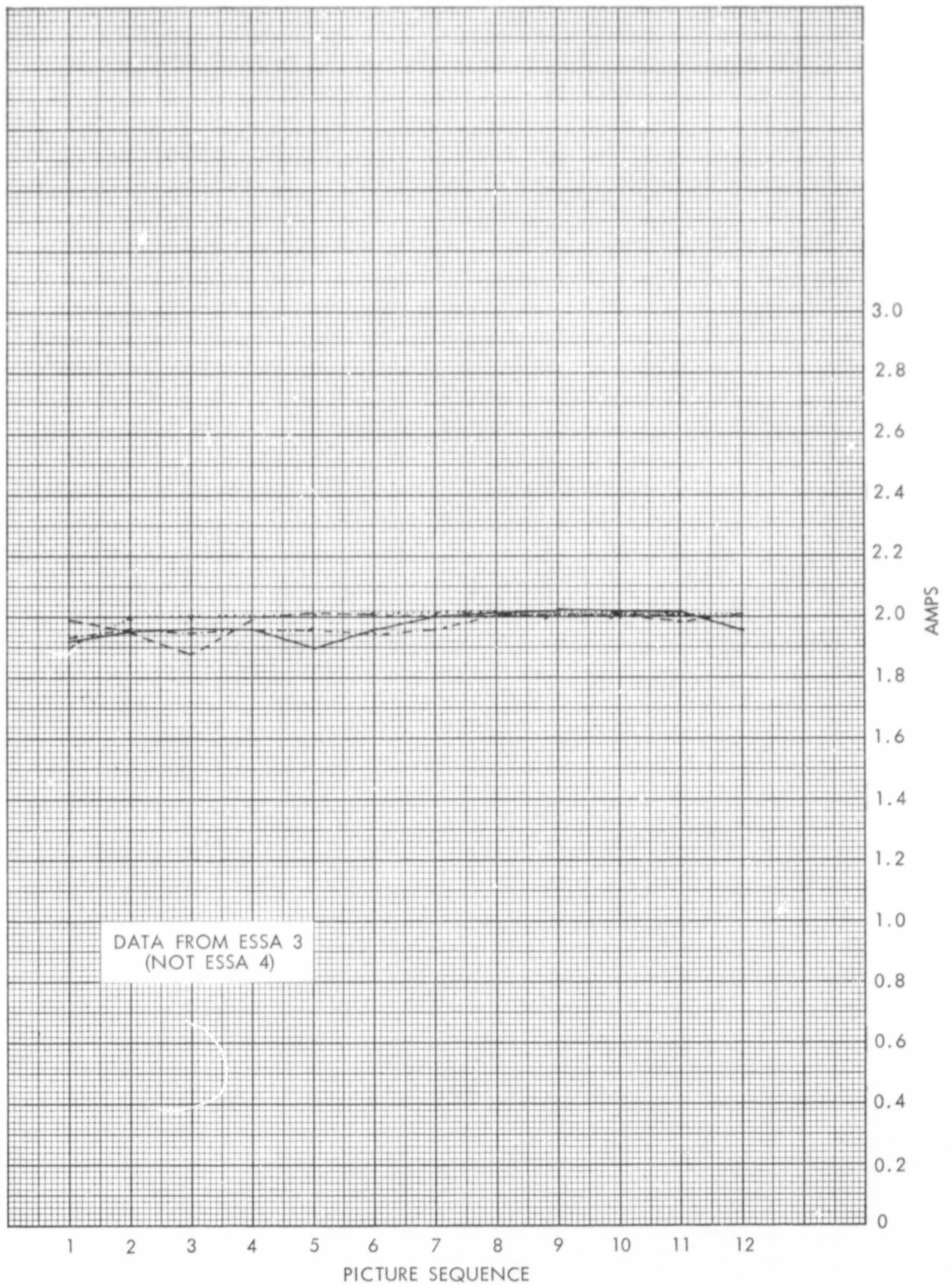


Figure 25. Solar-Array Current

During revolutions 5518 and 5520, a partial picture sequence (Figures 26 through 31) was run for two purposes:

- To evaluate operation of the spacecraft as a whole when gamma is increased past 90 degrees enough to reach "operational" temperatures again
- To evaluate operation of the secondary spin counting of the spacecraft when the HCI's are not aimed at the earth

The pictures came out with no observable degradation, and the timing was as close as we could predict without knowing the exact times at which the HCI's lost and reacquired the earth. This procedure finally confirms the operation of a backup system we had not had occasion to use before. The significance of the picture and the spacecraft systems during this particular test may prove to be of operational use: the data suggest that, by using mission mode and a gamma of about 110 degrees, the spacecraft can reach operational temperatures with about 10 degrees less gamma than if the spacecraft had been turned around to obtain gamma of less than 90 degrees. Considering the slow rate of spacecraft orbital drift in relation to the sun, this procedure could put a spacecraft back into mission-mode operation much quicker than turning it around as soon as it reaches a high-noon position (spacecraft in line between the sun and the earth; i.e., local apparent noon).

Figure 26. Dummy Frame, Revolution 5518

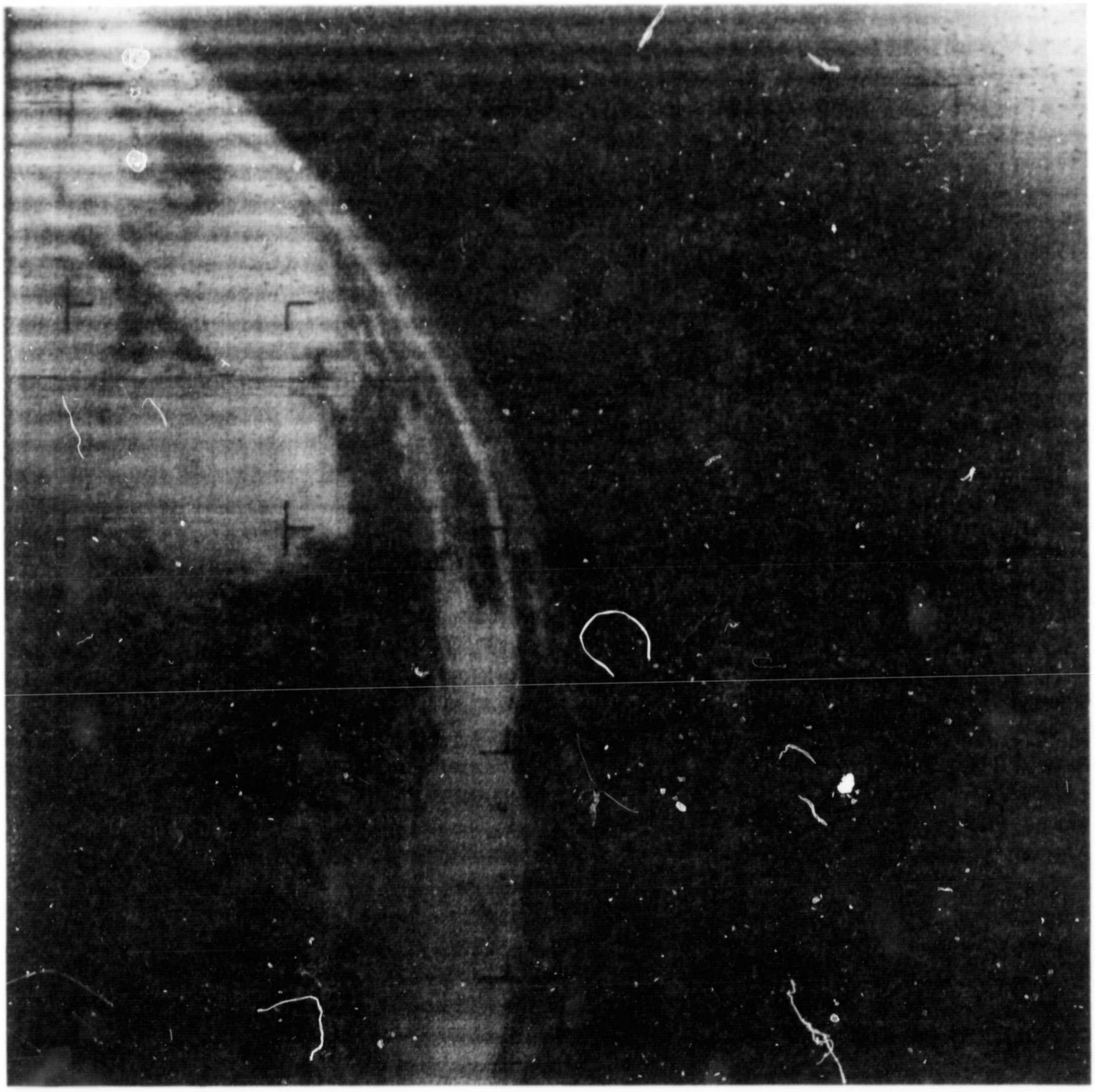


Figure 27. Spacecraft at Extreme Roll Angle, Picture 1

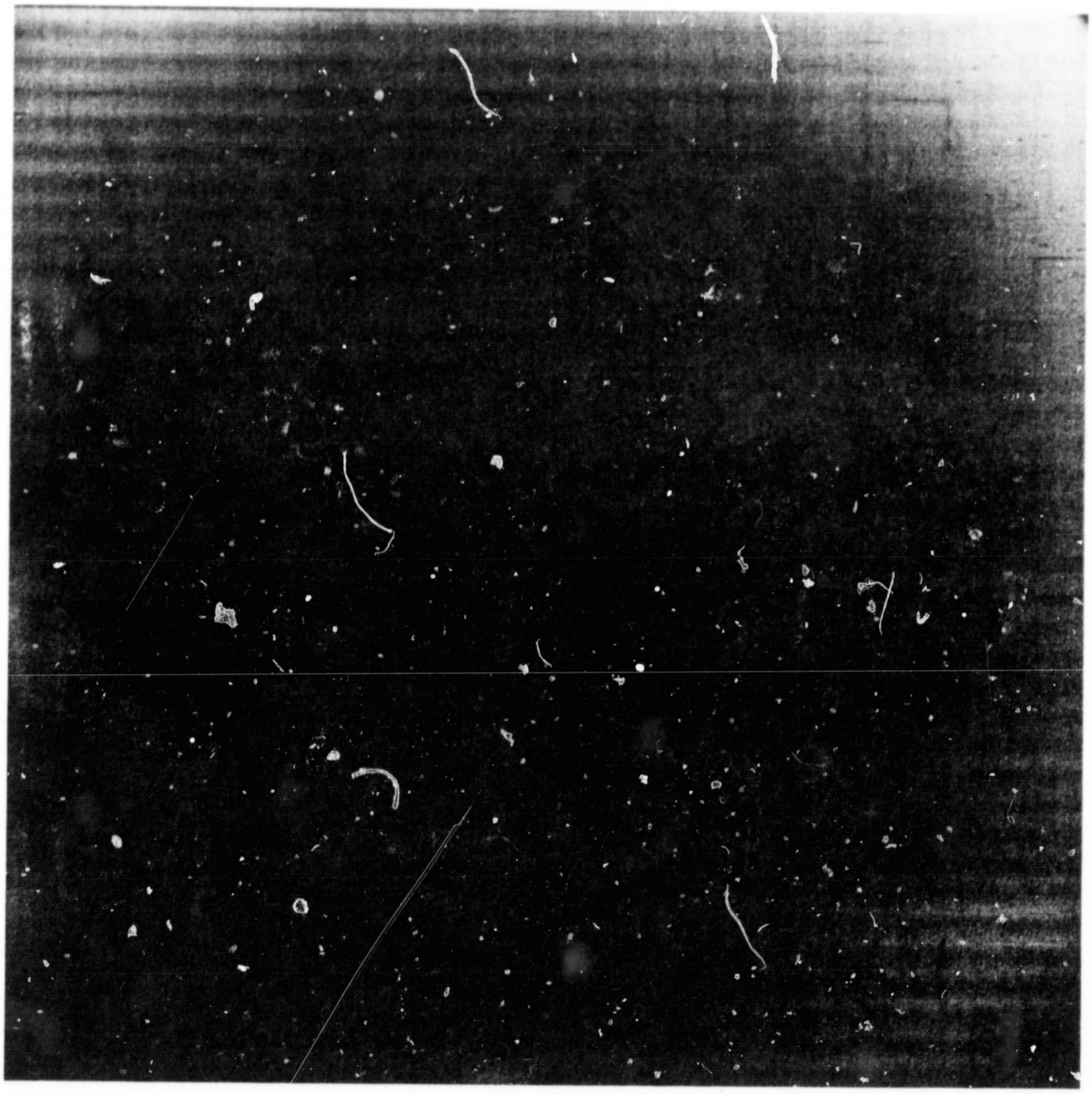


Figure 28. Spacecraft at Extreme Roll Angle, Picture 2

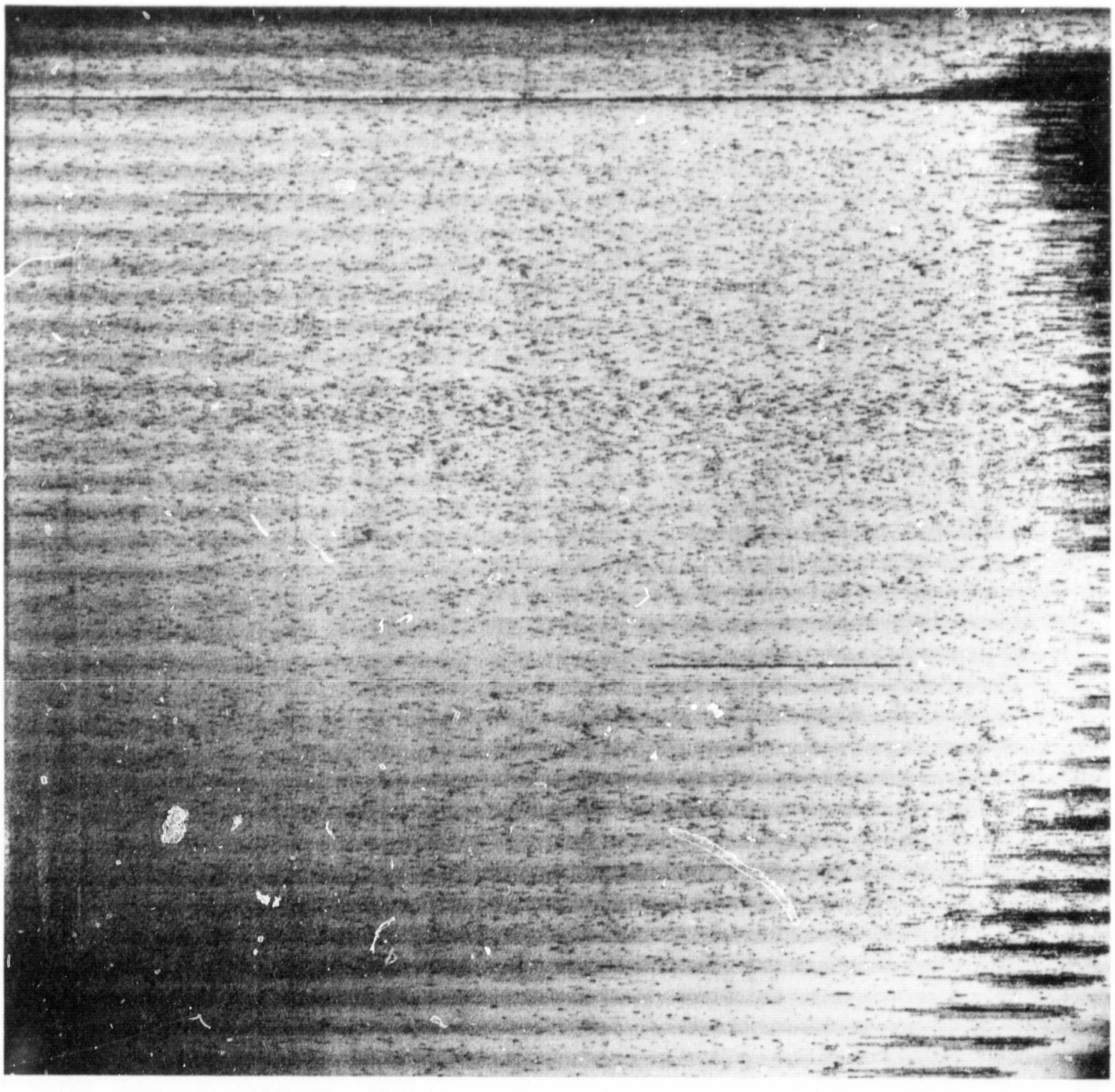


Figure 29. Dummy Frame, Revolution 5520

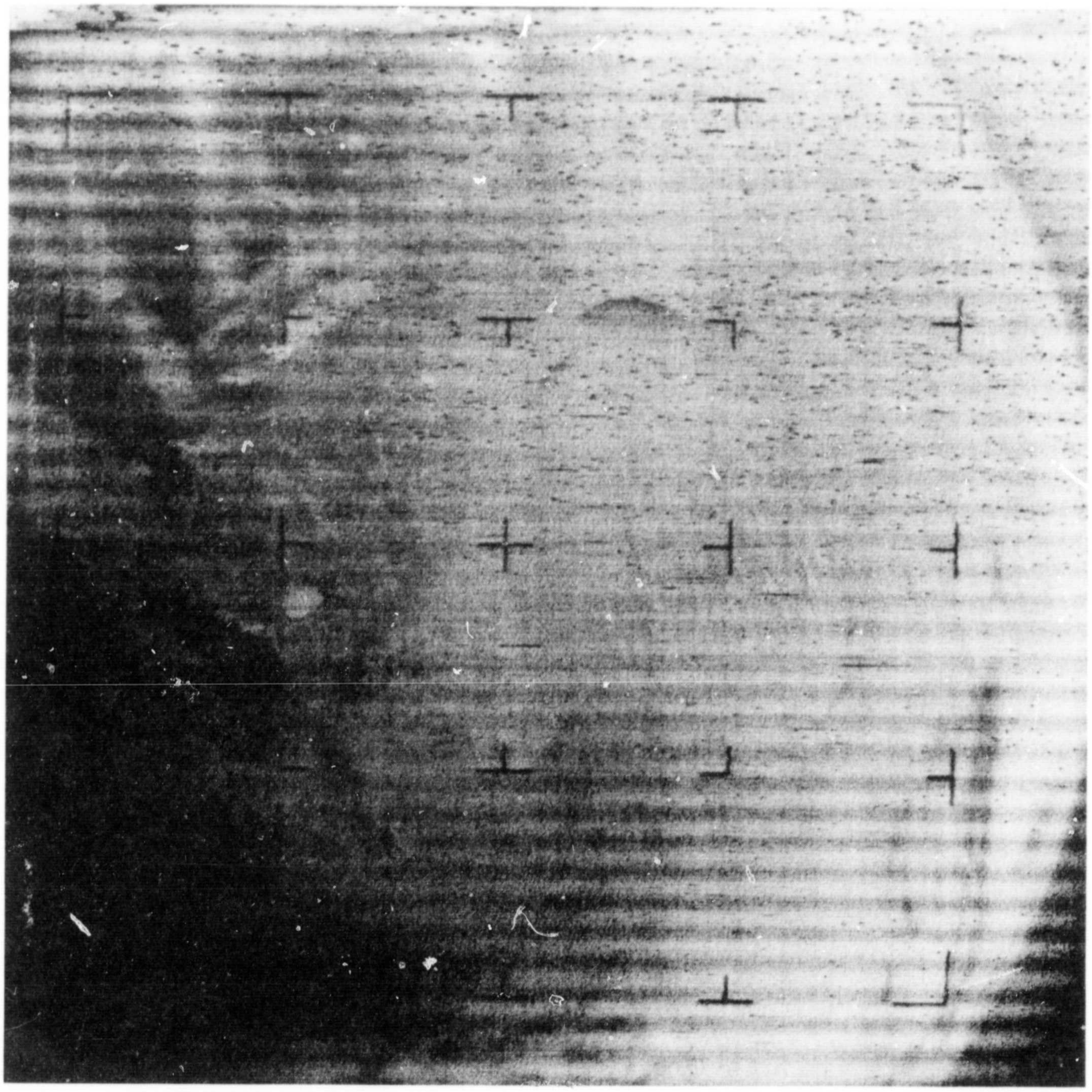


Figure 30. Spacecraft at Extreme Roll, Picture 1

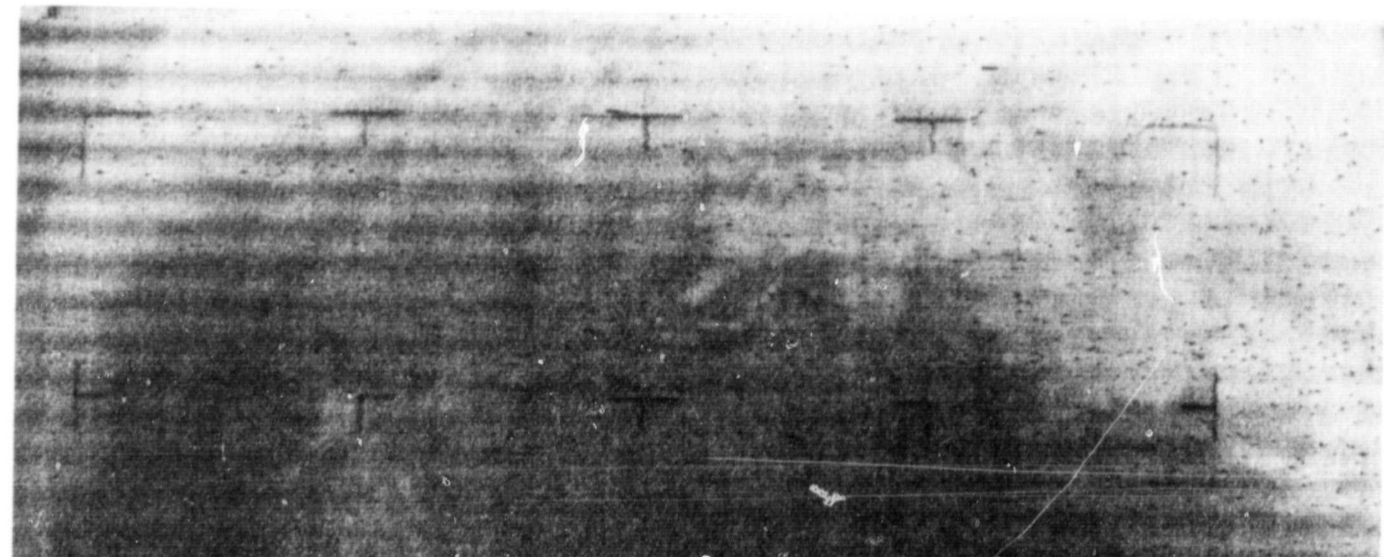


Figure 31. Spacecraft at Extreme Roll, Picture 2

GROUP IV TESTS

A. Tests

1. Switch MASC polarity when MASC coil is powered.

2. Switch regulators with full power on.

3. Switch cameras with full power on.

B. Purpose

1. The MASC polarity will be changed while a MASC sequence is in progress (preferably during the powered portion of a cycle) in order to test the spacecraft's vulnerability to an undesirable command. The MASC switching circuits will be operated while carrying full current so that any abnormal reaction will be apparent. No damage is expected from this test, but the particular command combination has never been tested on an operating spacecraft.

2. Regulator 2 on ESSA 4 has never been used. The purpose of this test is, first, to try regulator 2 in normal operation to see how well it has survived a year of storage without action. A picture sequence with one or two shutter throws will be programmed in order to use regulator 2 under normal load conditions.

   After regulator 2 has proved satisfactory, the regulators will be switched under full spacecraft power load (during a picture). The switch to regulator 1 will be made without the normal OFF time between switching, in order to impose the greatest stress on the regulator; the resulting transient may cause some damage.

3. The next test is to determine whether the camera 2 shutter board will fail when switching powered cameras. Camera 1's shutter board failed under similar circumstances during the launch checkout; design changes have been made to prevent this happening to ESSA 6 and succeeding APT spacecraft. However, it could happen to ESSA 2. The cameras will be switched during a picture sequence (frame readout) to see if something blows.

C. Procedure

1. Reverse the MASC polarity during a normal pass when no other programming is planned. Start a normal double MASC-coil spinup (MASC-POS) program; during the powered portion of a cycle, send a MASC-NEG command. In order to do this, it may be necessary to send the command by manual direction. Switch polarity during an unpowered portion of the cycle, using either a MASC-NEG or MASC-POS command, whichever is opposite to the one in use.

2. Switch the regulator during a normal pass when no other programming is planned. First, put in a normal program to switch to regulator 2 and leave it in normal use for at least an orbit or two, in order to be sure that it is operating properly. During a later orbit, initiate the command to switch back to regulator 1 without regard to the normal delay procedures. Record telemetries before and after to determine spacecraft status. If time permits during this orbit (or on a later orbit), start a picture sequence over Wallops in daylight with camera 2, to be sure that the spacecraft is still operating properly; then, during a picture readout, immediately switch regulators again to observe the effect of a regulator-change command when spacecraft is under full load.

3. Perform the camera switch-under-power test on a fairly high-elevation pass over Wallops in daylight. Program a picture sequence to start with camera 2 selected; halfway through the first good picture frame, manually send the command to switch to camera 1. Get a succeeding complete good frame readout before shutting off the camera system. Record telemetries during and between pictures.

   Switch the cameras again—back to "good" camera 2—during the next available Wallops daylight pass. Switch over again during a frame readout, and record telemetries during and between pictures.

   A complete and normal picture (with shutter throw) must be obtained from camera 2 in order to determine whether it is operating satisfactorily after these switching tests.

   Selection of programmers, transmitters, etc. is optional during these tests. The above directions assume that the spacecraft will be in normal mission mode and within spin tolerance.

D. Results

The Group IV tests, which were potentially destructive, were the last of the ESSA 4 postoperational tests. Their purpose was to do fast switching of regulators, MASC polarity, and cameras, and to observe the results.

The first step—a switch to regulator 2, never used on this particular satellite—went through without incident and the regulator was found to be in excellent condition after a year in storage. This regulator had never been checked since launch.

With the integrity of regulator 2 verified, the next experiment was to shift from one regulator to the other without delay. This occurred without discernible spacecraft damage. However, as all power was momentarily removed from the programmers, we effectively lost our remote-word and stored random bits in the remote-word register when power returned. This was expected, and is not considered a problem but rather a side effect to be taken into account.

MASC polarity switching under full load was the nearest to a problem that was encountered: Actual changing back and forth in MASC polarity occurred with no sign of any problem to the spacecraft, but on revolution 5743-G we observed an anomaly in the MASC trigger. Instead of the normal 50-percent-on/50-percent-off telemetry indication, we observed a 70-percent-on/30-percent-off indication varying throughout the pass (reversed 30-percent/70-percent in negative MASC). Examination of the SCO-3 telemetry recording showed that the cause was apparently sun interference on one HCI sensor, showing up after the earth/sky transition of the opposite HCI sensor. This pulse occurring during "sky time" caused a false MASC spin trigger. Gamma at this time was 77 percent (DSAI readout is either 77 or 80 degrees, as bit two is always zero). Figures 32 through 39 are excerpts from an 8-channel Brush recording from revolution 5743-G; this series of charts shows MASC switching while the spacecraft is mistriggered by a pulse which shows up in the HCI lines.

The anomaly was caused by:

- field-of-view of the HCI sensor
- slight canting of the HCI's from each other and the spacecraft (as it appeared in one sensor only)
- the low threshold of the spin trigger which provides MASC triggering

This condition could have resulted in a spin-count error or an off-earth picture.

When the spacecraft was rolled to a lower gamma, the problem disappeared, indicating that the sun was no longer in the field-of-view of the HCI sensors and no damage had occurred.

The final test was to switch cameras under power. The camera 1 shutter failed during the switch and did not recover. Switching from camera to camera with a picture sequence in progress was common practice before, and has been successfully done many times at RCA/AED in the course of evaluating the ESSA 4 degradation. The camera 1 failure was later attributed to a defective fuse on the shutter board. The effect of the switch and its accompanying failure was a loss of the last portion of the picture in progress, although the next picture in the sequence appeared on schedule with the newly selected camera 2. No obvious damage was apparent. This switch was made while the readout mode prevailed; the conclusion is that an inadvertent camera switch should not damage the camera or its electronics.

Chart 1: start of 5743G; spacecraft in ascending node. Note sun interference appearing on one HCI sensor and not on the other; examination of this and the following recordings suggest that HCI is seeing the sun, but that HCI 2 is not. Note fast change in sun-pulse relative position throughout this pass, as shown in the following charts.

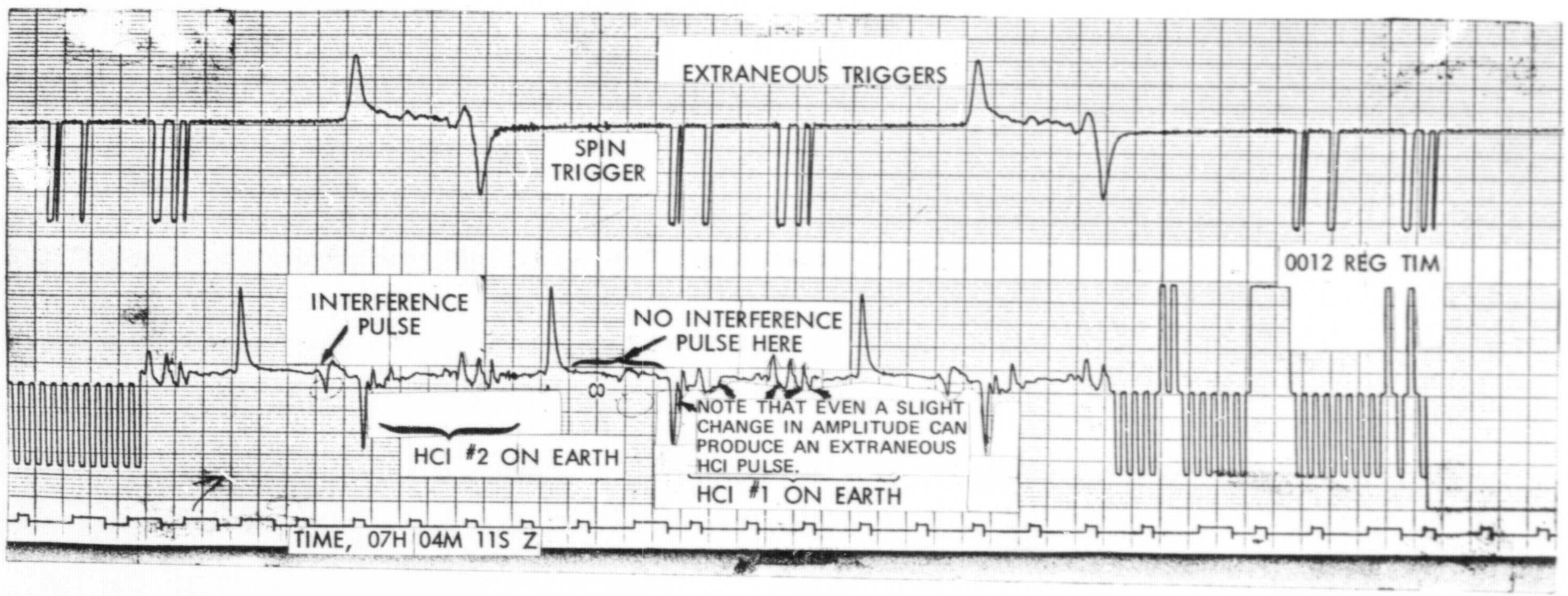


Figure 32. Chart 1, Revolution 5743-G

Chart 2: start of a MASC-POS sequence. Note early switching as compared with the previous chart. Observe how small a signal is needed to generate a false or extraneous spin trigger.

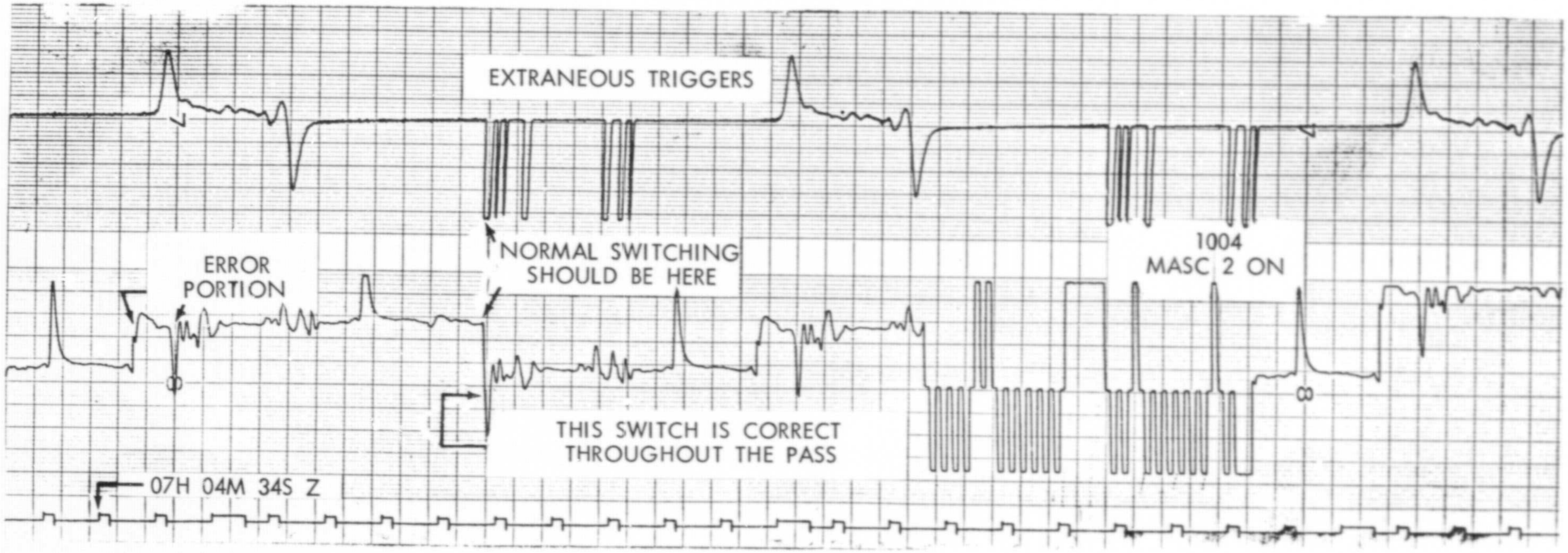


Figure 33. Chart 2, Revolution 5743-G

Chart 3: continuation of chart 2, spacecraft now in a double MASC-POS cycle. Note timing of early switching of MASC cycle in relation to spin-trigger pulse and the SCO 2 trace above it (AHI 2). Followed through this series of charts, this timing will be seen to change quite rapidly.

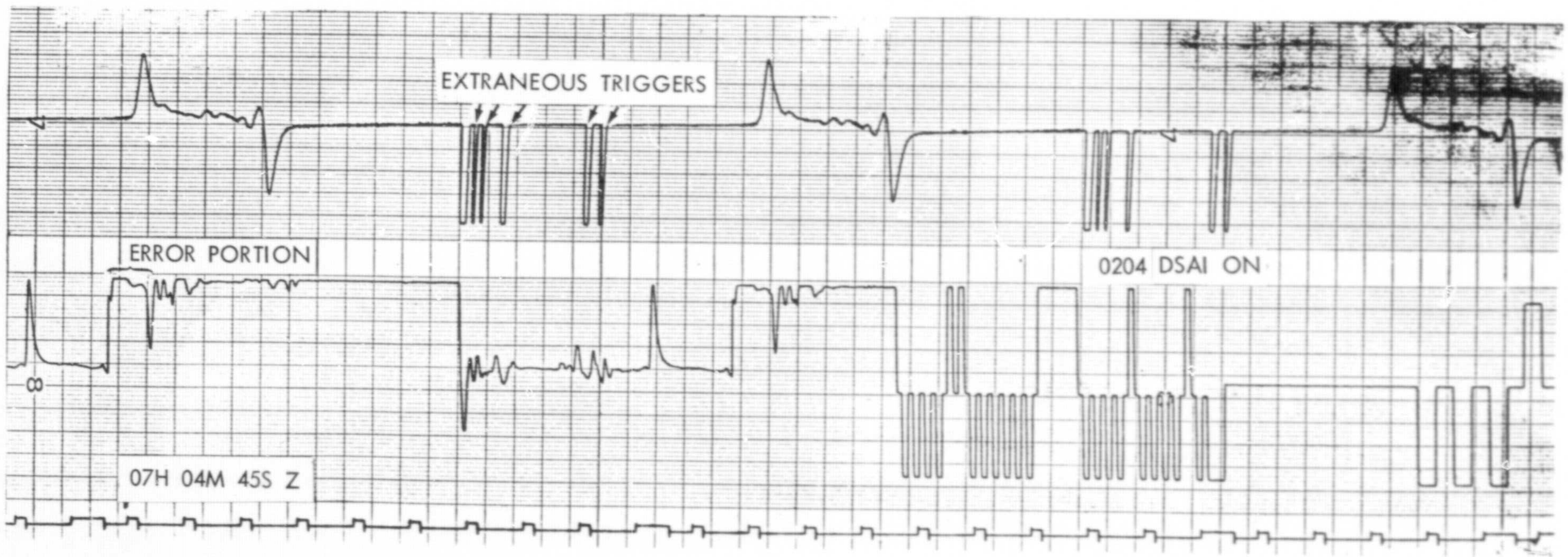


Figure 34. Chart 3, Revolution 5743-G

Chart 4: near end of first MASC-POS spinup and later in time than chart 3. Note how timing has changed: switching is now off by 35 percent on each switching cycle; spacecraft at this point, instead of having a 50/50 ON-OFF cycle, has a 65/35 cycle and, as a result, is only 65 percent effective.

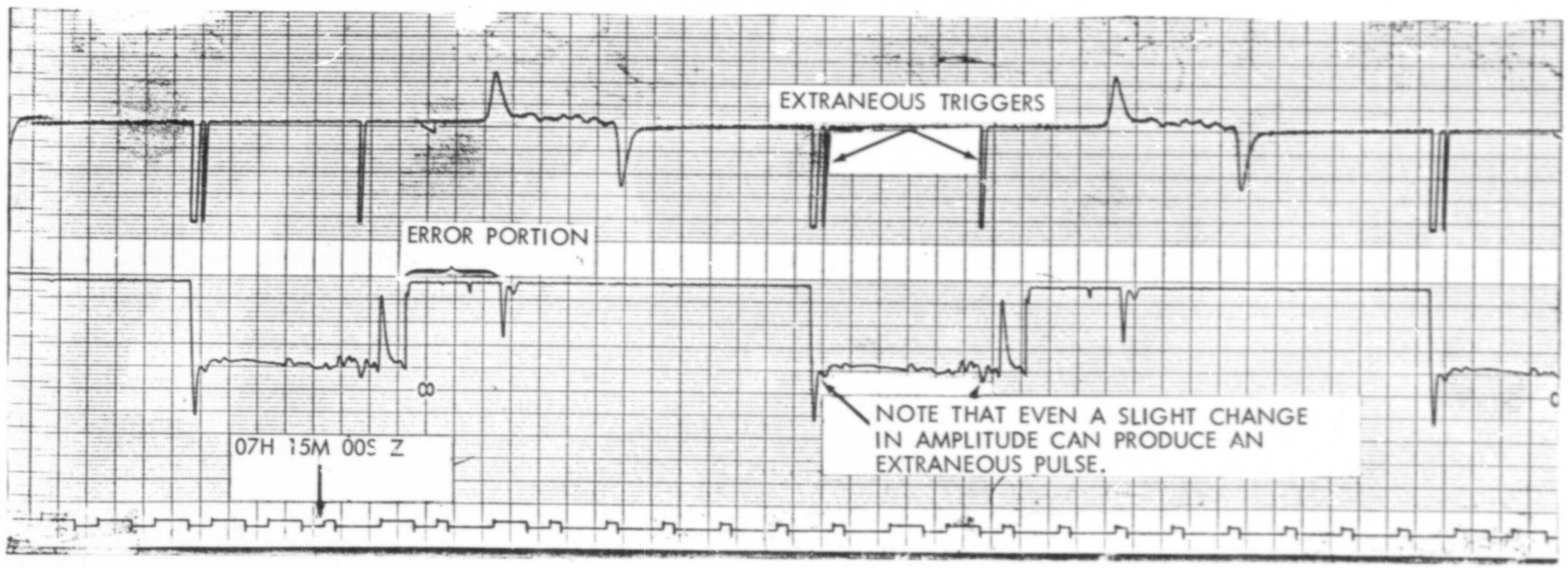


Figure 35. Chart 4, Revolution 5743-G

Chart 5: showing switch of MASC polarity in the middle of a cycle. Note that the cycle, still 65%/35%, is reversed in phase (compare cycle with spin trigger).

Figure 36. Chart 5, Revolution 5743-G

Chart 6: second MASC polarity switch under load; compare timing with charts 2 and 3.

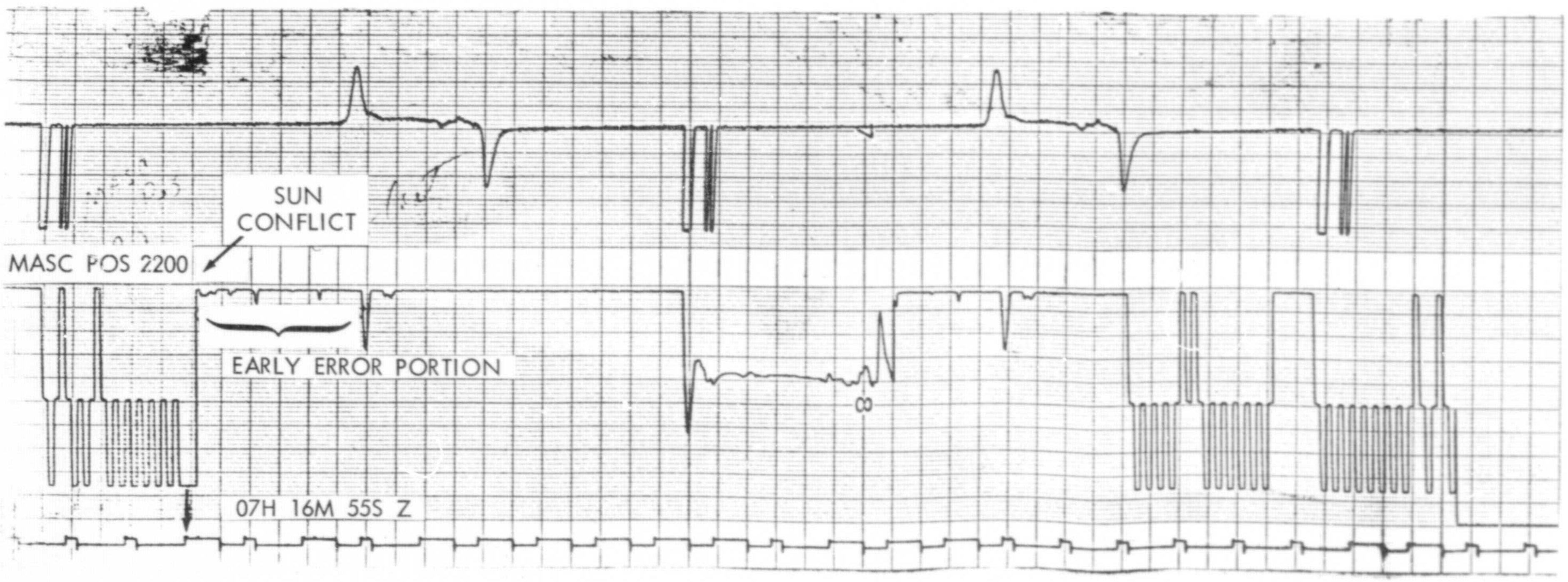


Figure 37. Chart 6, Revolution 5743-G

Chart 7: slightly later than chart 6, this is the final trim of the spin period.

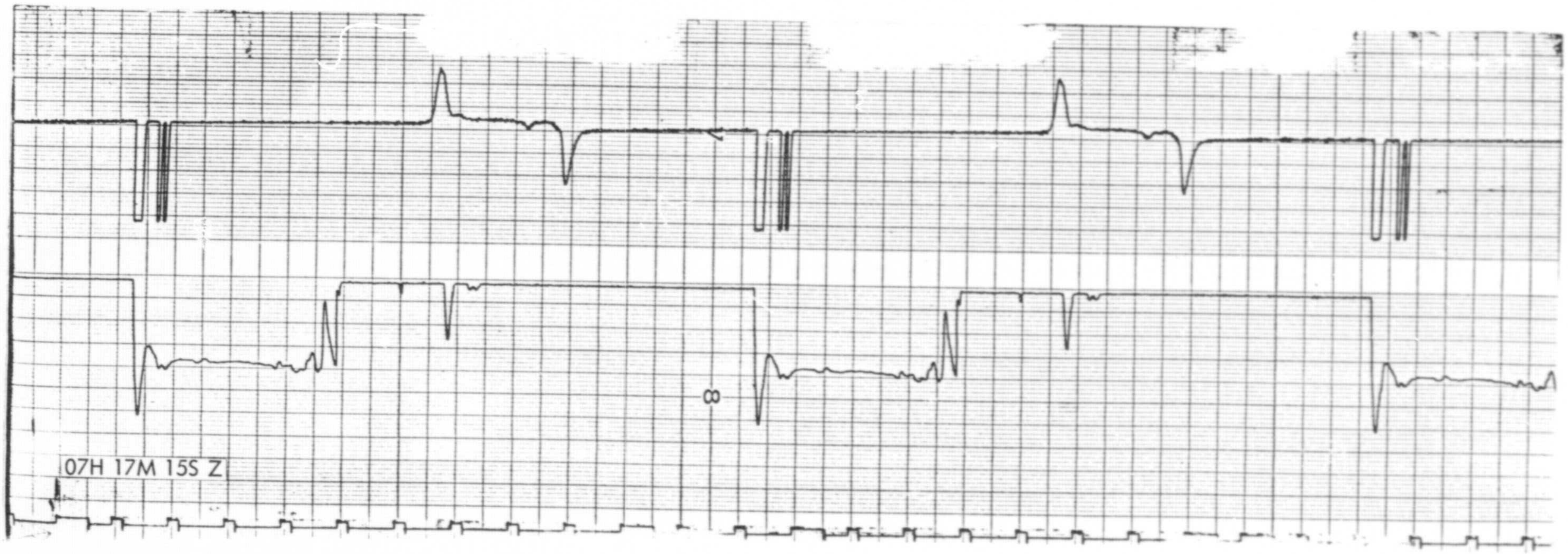


Figure 38. Chart 7, Revolution 5743-G

Chart 8: MASC OFF; compare with chart 1 and note how the interference has moved through the sky period.

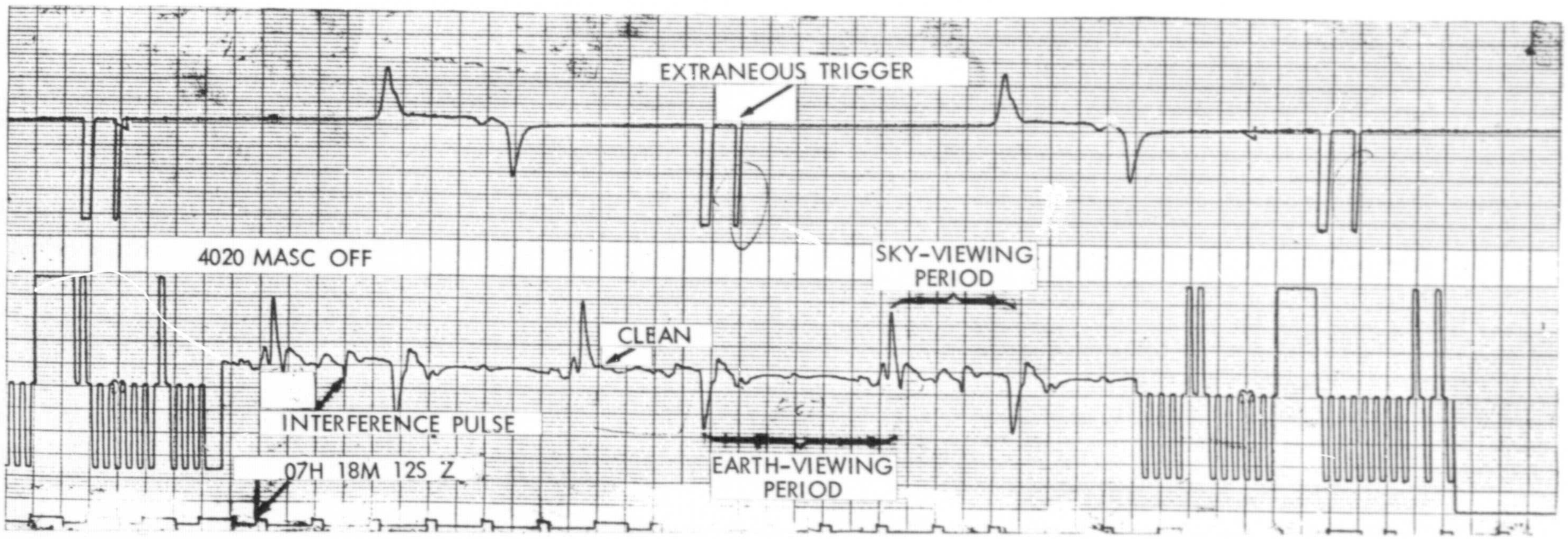


Figure 39. Chart 8, Revolution 5743-G